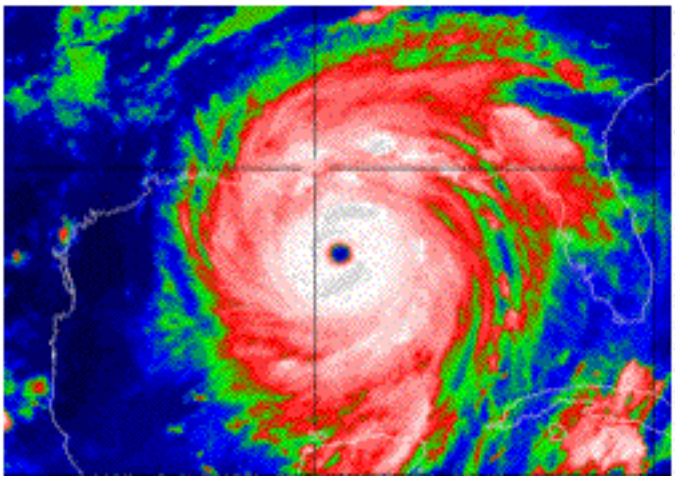
Extreme Earth

The Importance of the Geosciences in Science Teaching



A Science Education eBook

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Cover: Satellite image of hurricane Katrina, NASA

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Preface

Extreme Earth: The Importance of the Geosciences in Science Teaching is an eBook based on Art of Teaching Science blog posts written over the past few years.

Extreme Earth raises questions about the nature of science, especially as it relates to climate change and plate tectonics. Global warming has been in the public eye for years now, as scientific panels and independence scientific research studies have suggested that the changes in earth's weather and climate might, to some degree, be due to human activity, especially fossil fuel extraction and the burning of fuels resulting in a 25 – 30% increase in CO_2 in the Earth's atmosphere. Unfortunately the science of climate change has become politicized, and resulted in the what some say is a "head in the sand" approach to doing something about the changes going on all around us.

Extreme Earth is also about natural disasters that humans have no impact on the cause, but because of spread of human habitats into paths of hurricanes, and tornadoes, and along well-known fault zones, has resulted in horrendous experiences for millions of people. The flooding in Pakistan and in the United States over the past two years has exceeded any record kept in either country over the past 100 years. In the United States, the number of F4 (Devastating) and F5 (Incredible) tornadoes increased substantially in the spring of 2011, causing havoc to many cities and towns along their paths.

We've experienced a number of strong (6.0 – 6.9), major (7.0 – 7.9) and great (8.0 or more) earthquakes has been notable over the past few years, the cause of huge destruction. The Haitian earthquake destroyed a great part of that nation, and the recent earthquakes and Tsunami off the coast of Northern Japan destroyed the homes of millions of people, and knocked out three nuclear plants, creating one of the most severe nuclear crises in human history.

Extreme Earth explores these issues, raises questions for science teachers, and points to ways to involve students in these tumultuous events.

About the Author

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Introduction

As I put the last touches on this eBook, there are several hurricanes and tropical waves in the Atlantic and Caribbean And just a week ago, one of the most destructive hurricanes in U.S. History—Irene—destroyed buildings, and flooded entire communities from North Carolina to Vermont. Irene followed the East Coast's 5.8 magnitude earthquake centered near Mineral, Virginia.

Are these extremes in the weather the new norm, or is this simply part of larger cycle of climate change. It is not an easy question to answer. According to one report, "The U.S. has had a record 10 weather catastrophes costing more than a billion dollars: five separate tornado outbreaks, two different major river floods in the Upper Midwest and the Mississippi River, drought in the Southwest and a blizzard that crippled the Midwest and Northeast, and Irene."

One researcher at NOAA suggests that the record-high nighttime temperatures this year is abnormal, and part of an ongoing trend that we've had since 1980. Some scientists indicate that global warming has helped intensify the temperature extremes and droughts, especially when combined with weather patterns such as La Nina. Other scientists, such as Judith Curry at Georgia Tech, who agrees that humans are changing the climate, notes that we've had severe extremes before.

This eBook will explore not only weather and climate related phenomena, but will also look into earthquakes and volcanoes, two important geological events that impact the lives of people around the world.

Nature's Extremes

In a recent CNN opinion piece, Orrin H. Pilkey, Professor Emeritus of Earth Sciences at Duke University, wrote about "when will we ever learn the lessons of hurricanes?" The U.S. is in the path of hurricanes that form in the Atlantic and move either into the Gulf or along the East Coast of the U.S. mainland. Pilkey is concerned that after the hurricane has damaged, or in many cases destroyed property, especially beach front buildings, we are quick to rush in to rebuild and in many cases, bigger and taller buildings in the path of future hurricanes.

Judith Curry, Professor of Earth and Atmospheric Sciences, Georgia Institute of Technology, in her published research, and in statements at hearing at the U.S. Congress, has concluded that "based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation.

Hurricanes aren't the only extremes we've endured. Tornadoes, flooding, drought, and wildfires have ravaged many parts of the country this year, and for some there seems to be no let up. In a National Oceanic

and Atmospheric Administration (NOAA) report, For example, the 30 year average for number of Tornadoes in April 135. In 2011, there were 875 tornadoes reported in April, and approximately 1400 for the period January – May, 2011.

Flooding has been extreme. With greater snowfall in the winter, and increased amounts of precipitation in the spring, the Mississippi watershed experienced some of the most severe flooding in history. According to NOAA, precipitation was nearly 300 percent of normal precipitation the Ohio Valley.

Drought, Record Triple Digit Temperatures, and Wildfires have set records never before observed in the Southern Plains of Oklahoma, Texas, and New Mexico. According to NOAA, the track of storms from the Rockies into the Central and Northern Plains cut off the Southern Plains, resulting in extreme drought and wildfires.

Earthquakes, Volcanoes, Oil Spills

Recently we have experienced a number of geological events that have caused havoc and misery to many people around the Earth. On January 12, 2010 Haiti was rocked with a magnitude 7 earthquake causing the destruction of the many cities and towns including the capital, Port-au-Prince. Then, on February 27, a magnitude 8.8 earthquake occurred off the coast of the Maule region of Chile, causing enormous damage to property and life. In late March, Iceland's Eyjafjallajokull volcano erupted for the first time in 200 years, and volcanologists predict that the activity could last for months. We all know the havoc that was created when European airspace was shut down stranding thousands of people. Then on April 20, the catastrophic explosion of BP's Deepwater Horizon occurred resulting in the death of eleven platform workers and injury to many others, and to perhaps the worst oil spill in U.S. history. A month later, oil was still gushing out at rate that exceeded the estimated 210,000 gallons/day.

In each of these cases, the destruction to property, and the loss of life varies from one disaster to the other, but they all have impacted the environment of vast regions of the earth and millions of people. In the case of the earthquakes and volcano, students' understanding of theory of plate tectonics will help them understand how these geological events occurred. The geology of the Haiti and the Chile earthquakes provide students with a deeper understanding of plate tectonics, and how the earth's crust works. Iceland's volcano occurred along the interface between two tectonic plates, where new crust is moving to the surface from deeper in the crust of the earth. It is at this interface that these two huge tectonic plates are moving away from each other. Quite different from the compressional activity of the tectonic plates that come into play in the case of the Haiti and the Chile earthquakes.

A few month's ago the Governor of Louisiana wondered why the EPA had funds in its budget for "volcano monitoring." He lashed out at this as an example of government funding gone amuck. In a post I wrote after that entitled Volcano in your backyard, the mayor of Vancouver begged to differ with the governor. Because of the BP's horrendous oil spill, the governor now finds himself in the middle of a very significant environmental disaster.

The U.S. produces about 9 million barrels (1 barrel = 42 gallons) of crude oil per day, and imports about 13 million barrels of crude. The BP oil spill is spewing 5,000 barrels (view this Youtube clip) of crude oil into the Gulf of Mexico per day (210,000 gallons). These are BP estimates, and they're many geologists who think the spillage is much greater. Nevertheless, this is a huge amount of oil that is being pumped into the Gulf, and is threatening the entire Gulf Coast, and some fear that the oil could move up the East Coast of the U.S.

The Gulf Oil spill provides the context for a powerful STS teaching and learning experience for middle and high school students. To help students understand the oil spill, you might explore the visualizations shown on this website including what a 5,000 barrel/day oil spill looks like, how oil is explored beneath the ocean, how big is Deep Horizon oil spill, and many other questions.

A recent paper by Bulunuz and Jarrett in the Eurasia Journal of Mathematics, Science, and Technology Education explored the research on teachers' understanding about Earth and space science concepts. The paper has implications for us as teachers, and also science teacher educators.

Part 1. Extreme Weather

1.1. What Are Students To Make Of The Number Of Extreme Weather Events?

What do students think about the number of extreme weather events that appear to be occurring recently?

In my last post on this blog, I discussed how Native science could inform about global climate change. Some might say this is a stretch. I do not. In the Native science view of the environment, human communities are an integral part of ecological systems. This is a fundamental concept of environmental science. In this post I acknowledged reports written about the extreme weather events that have occurred not only this year, but for decades. In particular I called our attention to the unbelievable floods in Pakistan, the searing heat and fires in Russia, and the heat wave over much of North America.

Here is a link to an Extreme Weather Events map showing some of the extreme weather events of this past year. Note, that these are only a few.

Jay Gulledge, Senior Scientist and Director of the Science and Impacts Program at the Pew Center on Global Climate Change wrote on his Pew Center blog that there are important lessons to be learned from the "extreme weather" that has impacted many regions of the earth.

Here is a synopsis of his recent post on the Pew Center blog:

- The weather of 2010 continues the chaos of recent years. In the past six months, the American Red Cross says it "has responded to nearly 30 larger disasters in 21 [U.S.] states and territories. Floods, tornadoes and severe weather have destroyed homes and uprooted lives …" Severe flooding struck New England in March, Nashville in May, and Arkansas and Oklahoma in June.
- Nearly the entire northern hemisphere is experiencing a massive heat wave this summer. Back in February, heavy snowfall in D.C. prompted some politicians to decry global warming, but those voices are now silent in the searing heat that has gripped much of the world this summer.
- The current flooding in Pakistan is the worst in that country's history, with two million people homeless, 20 million affected, more than a million acres of croplands flooded, and signs of an incipient cholera epidemic.
- Russia is locked in the worst heat wave and drought in its documented history, with unprecedented high temperatures in Moscow and hundreds of wildfires burning out of control. The combination of extreme heat and thick smoke and smog from the fires doubled the city's death rate at the peak of the heat wave last week.

Gulledge raises the question: Is there a connection between these extreme weather events and global climate change? It's a question that is debated every time an extreme weather event occurs. And the question is one that we should engage our students with. Gulledge, one of the leading climate scientists answers the question, in part, this way:

As usual, there is no definitive answer about these specific events, but direct observations show that extreme weather events have become more frequent in the past half-century, and in the extreme cases that have been studied, the mechanisms are those that one would expect from global warming. At the most basic level, more droughts and heat waves are expected because of hotter, longer-lasting high-pressure systems that dry out the land, as witnessed in Russia. On the other hand, more floods are expected because hotter air evaporates more water from the surface and holds more moisture.

Gulledge's blog is a valuable resource for our students. Here you will be brought in touch with a website that provides reliable information on global climate change, and lead you to other sources of information.

1.2. Native Science and Global Climate Change

I wrote to Sergey Tolstikov, a friend who lives in Moscow to find out how he was doing with the extreme heat and fires that are ravaging Russia. He told me that he has been able to escape the heat by going to his daughter's flat and workplace, each of which has air conditioning. As he said, the combination of heat and smog is terrible. Temperatures have been above 90 in Moscow for many days, and in combination with fires that have been difficult to control, the atmosphere in Russia's capital city is dangerous for all people. And combine that with the fact that 1/5 of Russia's wheat harvest has been lost to the raging fires.

In Pakistan more than two weeks of flooding has devastated more than 14 million people, destroying homes, and displacing people. The floods were triggered by an unusually heavy monsoon season. According to one report, 1/5 of the nation is under water.

In the eastern part of the United States, millions of people are enduring the hottest July and August in memory, and the forecast is that this severe hot spell will continue into the near future.

Last winter, many cities in the U.S. experienced snowstorms that set records. This could possibly happen again.

There are two articles that are pertinent to the extreme heat, smog, floods, and snowstorms that we are experiencing. In a Science Progress article, Naomi Oreskes and Erik M. Conway suggest that the science of climate change has been distorted, and at the same time science is evoked as a defense. They describe how a handful of scientists obscured the truth, not only about climate change, but issues related to tobacco and to the government's "star wars" strategic defense system. As they point out, the climate change deniers use the same "play book" that big tobacco firms used to try and convince the public that smoking tobacco did not cause cancer.

The second article is a piece in the Huffington Post by Ryan Grim and Lucia Graves entitled 'Global Weirding': Extreme Climate Events Dominate the Summer. They quote environmental scientist David Orr, who suggests that these hottest hots, driest dries, wettest wets, windiest wind conditions are all part of pattern

that is expected given the rise in Earth's temperature. Orr's book Down to the Wire confronts climate collapse, offering an analysis of the destabilization of climate, and suggests a call to action.

Native Science

As I have written in my last two posts, I have been exploring Gregory Cajete's book Native Science. Native science provides an understanding of the global events that have been mentioned above. Cajete's book is subtitled "natural laws and interdependence" and this in itself gives us a first look at one the key principles of Native science. In Chapter 6 of Cajete's book, A Sense of Place, he outlines the science of living in relationship with nature:

> Key questions for traditional Native Americans included how individuals and the tribal community could ecologically respect the place in which they lived, and how a direct dialogue among the individual, the community, and the natural world could be established and maintained. Wherever Indigenous people lived, they found ways to address these questions of survival and sustainability in profoundly elegant ways. They thought of their environments "richly," and in each environment, they thought of themselves as truly alive and related.

One of the important things that Cajete does in this chapter is to describe the wide range of advanced technologies that Native peoples developed with an awareness of the Earth as a living organism. His examples include mining, hydraulics, and transportation systems, and in all of these cases he identifies how these systems were nature-centered, and further advanced than systems developed in the West. As Orr points out in his book, we have failed to heed ecological and climate trends, and tended to ignore the relationship that humans have with the earth.

1.3. Does Global Warming Cause Hurricanes?

No. That's the short answer. No one factor causes hurricanes, cyclones or tornadoes. However, global warming, (especially the warming of ocean surface temperature) could contribute to an increase the frequency and intensity of hurricanes. Recent studies suggest that hurricane intensities (more category 4 or 5 storms) may increase in the future. One scientist, Kerry Emanuel, published a report in Nature predicting that hurricane intensity should increase as global mean temperatures increase. Another report suggests that hurricanes will increase in intensity later in this century.

However, 2005 was one of the worst hurricane seasons ever (we ran out of names on the A-Z list, and had to go to Greek letters, alpha, beta, etc.) with 27 (that's twenty-seven) hurricanes. And some very surprising things happened. Katrina moved across Florida as a Category 1-2 storm, causing great damage, and then once it entered the warm waters of the Gulf of Mexico, and raged into a Category 5 storm, and hit New Orleans as a very strong Category 4 storm, resulting in the destruction of levees, the flooding of a great part of the city, and eventual evacuation of more than 500,000 people.

A new hurricane season has arrived. The first tropical depression (Tropical Depression 1—it will become Alberto if its winds reach hurricane intensity) formed west of Cuba, and could enter the Gulf and sweep across Florida and South Georgia.

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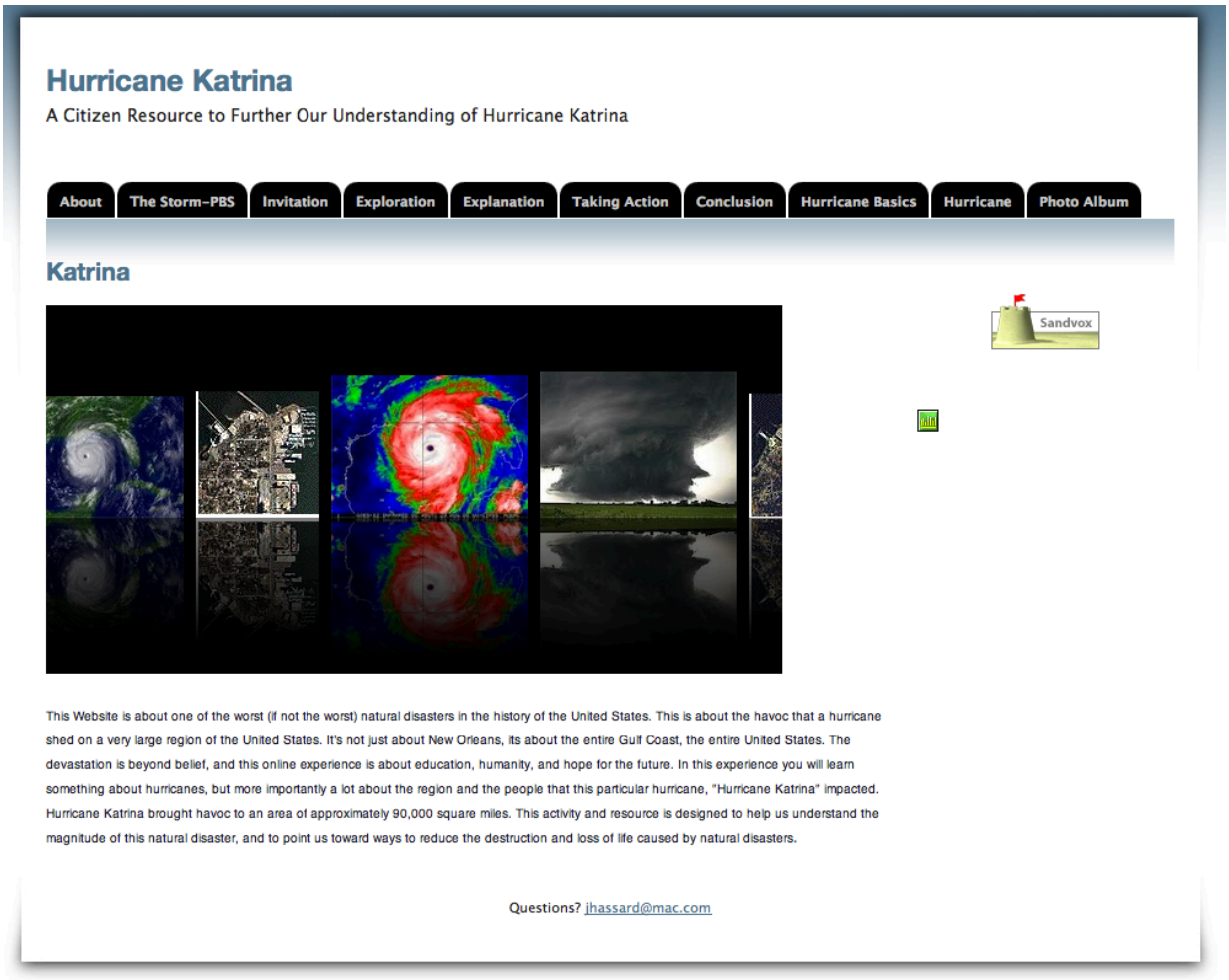
1.4. Hurricane Katrina: A Citizen Resource

The devastation of Hurricane Katrina was beyond belief, and might be the worst natural disaster in US history. Natural disasters, such as hurricanes, earthquakes, volcanic eruptions, floods, and other severe storms have impacted more than 2.2 billion people in the past 10 years. This is a very large increase from the previous ten years, and it will increase in the foreseeable future.

It is isn't that there are more hurricanes or earthquakes, it is that people have continued to populate high risk areas, and in many cases, not take the precautions that might lessen the effect of these natural events. For example, in the case of the flooding of New Orleans, the The Times-Picayune Newspaper wrote a five-part series on the effect of a hurricane on New Orleans in 2002. It was a clear warning of what would happen to New Orleans in the event of a category 4 or 5 hurricane. The response of federal and state agencies has been considered by many as "unacceptable" and has led to a great deal of criticism.

Soon after Hurricane Katrina, I wrote an online citizen resource that is designed to educate and inform people about Hurricane. This Website is about one of the worst (if not the worst) natural disasters in the history of the United States. This is about the havoc that a hurricane shed on a very large region of the United States. It's not just about New Orleans; it's about the entire Gulf Coast, the entire United States.



Citizen Resource for Hurricane Katrina

The devastation is beyond belief, and this online experience is about education, humanity, and hope for the future. In this experience you will learn something about hurricanes, but more importantly a lot about the region and the people that this particular hurricane, "Hurricane Katrina" impacted. Hurricane Katrina brought havoc to an area of approximately 90,000 square miles. This activity and resource is designed to help us understand the magnitude of this natural disaster, and to point us toward ways to reduce the destruction

and loss of life caused by natural disasters.

Part 2. Global Warming
2.1. Teaching The Truth About Global Warming

Teaching Truth. That's the problem when we discuss and debate the scientific topic of global warming. As Tim Flannery points out, science is about hypotheses, not truth. One of the long-term problems in science teaching is helping students understand the nature of scientific research, and how science develops theories to explain natural phenomena. Much of science teaching is didactic—even today, after more than 50 years of improved science education research and curriculum development.

Theory in Science

For example, when students learn about a theory in science, such as plate tectonics theory, it is often done didactically by reading the textbook, and identifying the observations and data that scientists used to develop the theory. Although there are well developed pedagogically sound activities that would encourage students to develop hypotheses and theories to explain data, this is often not done. As a result, students do not learn to appreciate the nature of scientific ideas, and how they come about. They learn little about certainty (or uncertainty), truth, or falsifiability.

Now, back to the issue of global warming. As of this date there are only a few countries that have not signed the Kyoto Protocol limiting CO2 emissions: the United States and Australia are two of them. Politicians in these two countries claim they want to wait to sign until there is "more certainty" about the direction of the supposed climate change—-the warming of the Earth. The phrase used by politicians is, "well, the science isn't settled yet."

But as Flannery points out, science is about hypotheses and theories, and there is always some uncertainty in scientific ideas—there always will be. But, that doesn't prevent us from making predictions, and taking precautions. The obvious one is weather forecasting—done well, weather forecasts and severe storm warnings can save lives and property. We don't say, oh, let's wait until we have more certainty. Of course we don't. We make forecasts, with the knowledge that we can't be perfectly certain.

The Case of Earthquakes

Take the case of earthquakes. We cannot predict when an earthquake is going to happen, nor the exact position. However, we have years of data accumulated that have informed us of the high probability earthquake areas. And of course, we know that many of these areas that are earthquake prone are related to plate tectonics theory.

Most of the earthquakes that we hear about and that seismologists observe occur along the boundaries between crustal plates, such as in California, along the San Andrea Fault. As result of our knowledge of earthquakes, governments have insisted on making use of this scientific data and theory, and passing laws that insist on improved building conditions. In California there are laws that regulate buildings based on fault

zones identified by the California Geological Survey, and citizens can obtain maps that show where these are and take the necessary precautions.

And we do this knowing that there is still uncertainty about earthquakes, when they will occur, and how intense. But we act on the scientific data and theories.

Global Warming

It should be no different with global warming. We have the data that supports the premise that the surface temperature of the Earth is increasing. And this increase has taken place over the past 150 years. For the past 10,000 years, the earth's temperature has been about 57 degrees. Tim Flannery, in his book, The Weather Makers, points out that the Earth's thermostat is a delicate and complex phenomenon, and that carbon dioxide gas plays a crucial role in balancing the Earth's temperature.

About 150 years ago, there were about 270 parts/million of CO2 in the atmosphere. It is now 350 ppm, and at this rate would be about 500 ppm in another 100 – 150 years. If you compare satellite images of the polar and Greenland ice, you can observe enormous shrinkage in just 40 years. We also observe that sea level is rising, and we find that plant and animal cycles have changed.

Migration of butterflies

For example, the migration of some butterfly species in England (where butterflies have been observed for a longer period of time than anywhere on Earth) have extended their migration further north because of warmer temperatures. And what is the certainty on all of this. It's not 100% certain. What about 95% certainty? Leading scientists say with high certainty that global warming is real, and that the warming is caused by emissions of greenhouse gases produced by humans.

Over the past 50 years we have extended our ability to use computer modeling to predict various scenarios of the future. For instance, some models show that if the CO2 levels were to double, that 57-degree average Earth temperature would jump to 62 degrees. Now that is only 5 degrees. But consider you own body thermostat. A rise of 3 – 4 degrees can be catastrophic to us. Whether the Earth's temperature will rise 5 degrees is not the issue. The issue is that the Earth's temperature is rising and the effects could be catastrophic. And it is time to take the lead of those nations or states (like California) that have enacted "green" laws to limit CO2 emissions.

But we haven't as a nation. Why not? Well, it goes back to a statements made by politicians saying that they want "more certainty" about the effects of global warming before they will act.

Remember Tobacco and Science Research?

We did the same thing with tobacco. Tobacco companies hired scientists who portrayed their research as credible, and then the tobacco lobby used that "data" to support their political and economic point of view

that smoking had not been proven to cause diseases such as lung or throat cancer. And this went on for years.

The tobacco lobby told people that smoking was okay; the scientific and medical evidence was conclusive that smoking did cause many diseases. Dr. Jeffrey Wigand, a research scientist and Vice President for a large tobacco company decided that the tobacco industry was defrauding the American public. He met secretly with the FDA and showed how the tobacco industry altered nicotine to make it stronger, and therefore more addictive. Wigand was fired, and sued, but an agreement was reached between him and tobacco. He later became an award winning high school science teacher. His story was told in the movie, The Insider.

The evidence supporting global warming is conclusive. If the temperature of the earth continues to rise in the near future (and 150 years is nothing in geologic time), then the health of the Earth, and its inhabitants is at risk. It is very easy for those who do not like the idea of the United States government embracing the science of global warming to find a few scientists here or there (as the tobacco companies did), and put them up as a poster child for claiming that global warming is an “environmental wacko” idea.

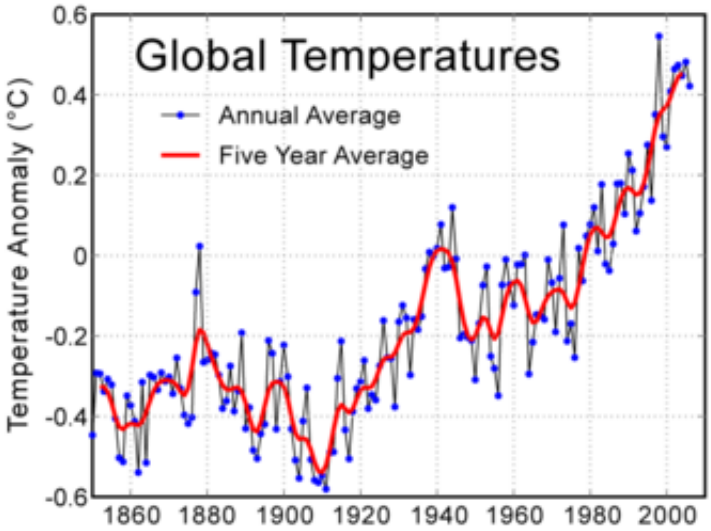
A few scientists here, a few radio talk show pundits there, and bingo, the huge body of scientific evidence showing the earth is heating up by CO2 emissions is questioned, and decisions that should be made about limiting greenhouse gases are put on hold. And of course, I haven’t mentioned the politicians that fear financial support from companies who claim that limiting CO2 emissions will be bad for the economy.

2.2. Views of Global Warming and Climate Change

Last week I wrote several entries on the topic of global warming, and most recently on legislation at the Federal level related to global warming.

Is the Earth warming?

Is the Earth warming? According climate change scientists, the answer is yes, as shown in the graph below. However, making policy changes, as we have discussed here in this blog, is not simply going to happen because the data shows that we should. Policy makers, and the general public are the ones that are going to enact legislation, and support the legislators, respectively.



The Pew Research Center has conducted a number of interviews related to global warming. Their most recent investigation of global warming was in January 2007. In this questionnaire, which has been repeated at least four times, 70% or more of the respondents agree that there is "solid evidence" that the earth is heating up, as shown in the chart below (Stable Views of Global Warming). The most recent survey shows that 77% agree with the global warming theory. But when asked about what is the cause of this warming, 47% (in the two most recent polls) say it is due to human activity, whereas 20% say it is due to natural causes.

Political Views of Global Warming

When political views are used to make comparisons of views of global warming, the differences are very sharp. The Pew Center calls them "polarizing." 54% of conservative republicans agree that earth is getting warmer, while 92% of liberal democrats agree. However, when we look at the middle of the political spectrum, there is little difference in views. This might be a good omen, in that moderate republicans and moderate democrats appeared to do very well in the last election.

Where does global warming stack up with other pressing global issues? In the same poll, global warming does not stack up very well compared to other global problems. It was near the bottom of the list for republicans, democrats and independents. Independents and republicans put terrorism at the top of their list, whereas health care costs was first on the democrats' list.

However, in another poll that looked at top foreign policy priorities, scientists and engineers put climate change first, state and local governments identified energy independence, where as terrorism and defense were identified as top priority for the general public, the military, the media, religious groups, and the academic and think tank communities.

Student Views of Global Warming

Several years ago, researchers working on the Global Thinking Project investigated the views of secondary school students in America and Russia on global environmental problems. Students were asked to rank a set of problems that were presented to them, as well as add problems to the list that they felt were important.

In the study, Citizen Scientists: Student Experiences in the GTP Georgia/Russian Exchange Project, American students identified air pollution as most important, and ranked the greenhouse effect and global warming fifth on the list.

The Russian students identified air pollution and global warming at the top of the list. They also identified nuclear arms and testing as an important global problem. It would be interesting to repeat the study, given the way the world has changed since 2001. Here are the results in list form.

American Students

1. Air Pollution
2. Ozone depletion
3. Air pollution
4. Rainforest destruction
5. Greenhouse effect and global warming
6. Landfills and waste disposal
7. Littering
8. Overpopulation

Russian Students

1. Air pollution
2. Global Warming
3. Water pollution
4. Ozone layer
5. Extinction of living species
6. Nuclear arms and testing of weapons
7. Solid waste disposal
8. Overpopulation

So, we see that the views on global warming are mixed. There are some people in our society, and in many other countries, that believe global warming is a threat to the future of life on the earth, and that governments need to take action immediately. Others do not rate global warming as the most important problem facing us. What do you think?

2.3. The Anthropocene Geological Epoch & Global Warming

A few years ago Paul Crutzen, a Nobel Prize winner for work on the ozone layer, proposed a new name for the geological epoch based on the effects of human civilization on the earth. He proposed that the new epoch began in the early 1800 and should be named the Anthropocene Epoch. You can read a good pro/con on the proposal at Andrew Alden's geology site. As Alden points out the present geological epoch is the Holocene, which began about 12,000 years ago, about the time when the most recent glacial ice began to retreat from North America and Europe. It also coincides with the rise of human civilization.

Role of Humankind in Geology and Ecology

Crutzen and Eugene Stoermer, in their announcement to emphasize the central role of humankind in geology and ecology, proposed the term Anthropocene for the current geological epoch. They said:

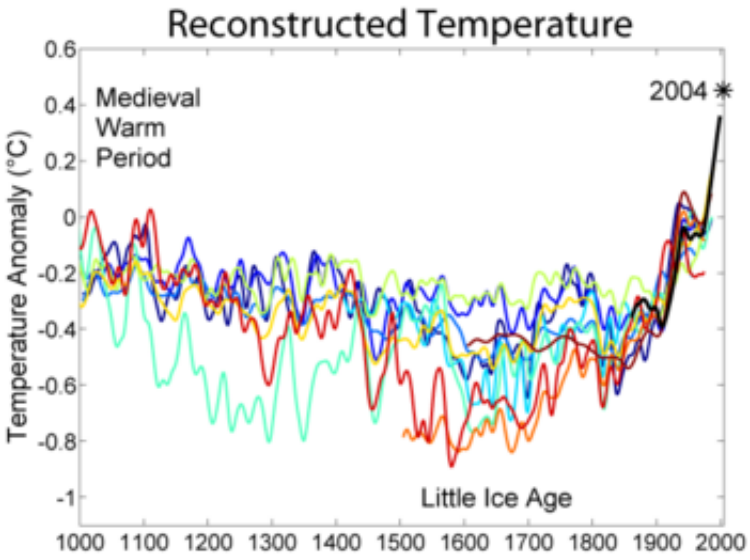
To assign a more specific date to the onset of the "Anthropocene" seems somewhat arbitrary, but we propose the latter part of the 18th century, although we are aware that alternative proposals can be made (some may even want to include the entire Holocene). However, we choose this date because, during the past two centuries, the global effects of human activities have become clearly noticeable. This is the period when data retrieved from glacial ice cores show the beginning of a growth in the atmospheric concentrations of several 'greenhouse gases", in particular CO2 and CH4. Such a starting date also coincides with James Watt's invention of the steam engine in 1784.

There are others that believe that the effects of human activity on global warming started earlier than the 18th century, and that human farming might have started the warming trend. William Ruddiman proposes that this warming may have started as early as 8,000 years ago (Known as the Early Anthropogenic Hypothesis).

Zooming Out in Time

John Baez's Zooming Out in Time is a powerful slide show of a talk he gave at the Long Now Foundation about climate change. Zooming out is a way of changing perspective and helps us understand why a few degrees of warming can be troublesome to us when compared with other climate change episodes in the past. The Long Now Foundation supports Seminars About Long-term Thinking that "promote 'slower/better' thinking as opposed to today's 'faster/cheaper' mind set.

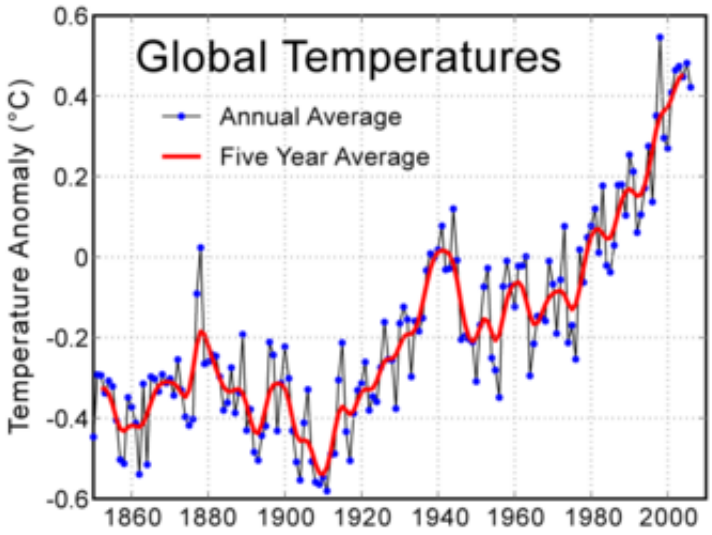
The changes we observe going on in terms of temperature increase, rising sea level, species migration north, climate zones moving north, all are related to human activity, and most scientists point to our emitting greenhouse gases into the ocean of air. The graph below shows the reconstructed temperature of earth back to A.D. 1000. Note that the Earth was relatively cold until the 18th Century.



Source: globalwarmingart.com

Global Temperature Changes

The following graph shows temperature changes since 1860. In both of these graphs, the one above and one below, the big problem is how fast the temperature has changed since about 1860.



Source: globalwarmingart.com

This proposal, and the observations surrounding the impact of humanity on the earth's atmosphere is a powerful topic for science teachers.

Resources for Teaching

There are a number of resources that I would recommend.

Firstly, I would start with Tim Flannery's book, The Weather Makers: How Man is Changing the Climate and What It Means for Life on Earth. The book is extremely readable, and there is a supporting website that also includes activities for students.

Another resource is the EPA website on climate change. It is extensive, and includes resources and activities for students.

You should also check the United Nation's website on climate change, where you will have links to global initiatives, including the Kyoto Protocol, and the Intergovernmental Panel on Climate Change.

Here are some others:
The Exploratorium's Global Climate Change Research Explorer
The Pew Center's Climate Change Resource

2.4. Uncertainty and Global Warming: Using the Nature of Science to Deny and Cast Doubt on a Robust Scientific Theory

In their New York Times article, Material Shows Weakening Of Climate Change Reports, Andrew C. Revkin and Matthew L. Wald reported on recently released House committee (Oversight and Government Reform) documents that indicated that a White House official edited government climate reports to play up uncertainty of the human role in global warming.

The key word here is "uncertainty," and I want to show how one of the values underlying science is being used to undermine scientific thinking, and sway the public against the "near certainty" of sea level rise, shrinkage of the ice caps, thawing of permafrost, all caused by global warming.

I also want to link this to science teaching, and how the teaching of science might contribute to the problem.

Certainty of Science Knowledge

How certain is scientific knowledge? I came across a very powerful statement by Joe Katzman in his blog in which he was discussing uncertainty as a value in science. He said and I quote,

> Scientific knowledge is a body of statements of varying degrees of certainty – some most unsure, some nearly sure, none absolutely certain.

Uncertainty in science is relativistic. Or we might say that scientific knowledge is relativistic. Scientific knowledge is embodied in theories that scientists develop to explain natural phenomena, and as such the door is always ajar to seek further answers to questions unknown. It is a fundamental value in science to have a degree of uncertainty in our understanding of nature. But that does not mean that a theory is wishy-washy, or lacks precision?

One question to raise here, does secondary school science teaching reflect these principles, and are students helped to develop these ideas about uncertainty and theory? The short answer is probably not. This is not to say that science teachers do not involve their students in research and investigation, but it is to say that very few students are exposed to this kind of thinking, and many if not most of the courses that are taught use a direct or didactic method of teaching, rather than an inquiry approach.

Editing Science

Government officials (at the White House and at NASA), however, or as it seems have zeroed in on the word uncertainty and used it to cast doubt on scientific knowledge, at least as it relates to global warming. Two individuals in particular, according to Revkin and Wald's article are responsible for making hundreds of editing changes on scientific papers on climate change, and in one case, telling scientists they should watch what they say about climate change.

The House committee held hearings to find out whether the nonpartisan work of climate change scientists was distorted by political interference from the Bush Administration. The chair of the Committee in his opening remarks, said, "some of the information the Committee has already obtained is disturbing. It suggests there may have been a concerted effort directed by the White House to mislead the public about the dangers of global climate change.

He went on to say:

> The White House appointed an oil industry lobbyist – not a scientist or climate change expert – as chief of staff at the Council on Environmental Quality. We will hear from that former lobbyist, Phil Cooney, today. The documents we have received indicate he was able to exert tremendous influence on the direction of federal climate change policy and science. One of the key responsibilities given to Mr. Cooney and his staff at CEQ was the review of government publications about climate change. Mr. Cooney and his staff made hundreds of separate edits to the government's "strategic plan" for climate change research. These changes injected doubt in place of certainty, minimized the dangers of climate change, and diminished the human role in causing the planet to warm. Other key government reports – including an EPA report on the environment and an annual report to Congress on the changing planet – were subject to similar edits and distortions.

Then he went to add, “Another facet of the White House campaign involved controlling what federal scientists could say to the public and the media about their work. NASA scientist James Hansen is one of the nation’s most esteemed experts on climate change. George Deutsch is a young and inexperienced former NASA public affairs officer who was tasked with managing the public statements of Dr. Hansen and other NASA scientists.”

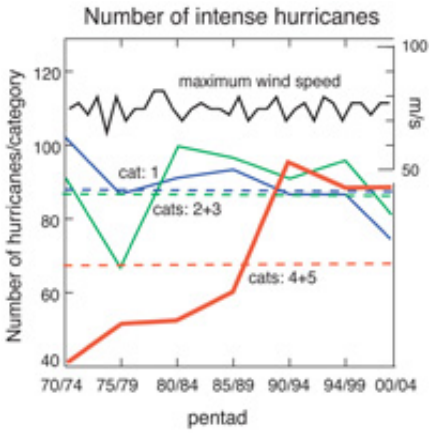
Part 3. Extreme Climate Change
3.1. Lessons from Hurricanes about Climate Change

If you live in Florida, one word you don't want to hear on the evening news is "hurricane." I lived in Florida in 1972 and 1975, and I don't recall a concern about hurricanes. But now, friends that I have that do live in Florida have been affected for the past two-three years by the devastation brought on by very powerful hurricane seasons. What can hurricanes teach us about climate change? How can teachers inform their students of changes that many scientists think are occurring to the earth's climates?

Two Schools of Thought on Climate Change

Nature's Calling. There are at least two schools of thought concerning climate change. Some scientists think that the increase in the number and intensity of hurricanes is part of a natural cycle of ebb and flow, and that we are in the midst of part of the cycle that followed a period of decreased hurricane intensity. They say that the earth's climates have changed through time, with periods of colder weather following warmer weather, increased hurricane intensity followed by ebb in intensity, and so forth. One scientist at Colorado State University who doesn't accept the concept of global warming, but rather sees natural cycles at work is Prof. Bill Gray. Gray is known as one of the most famous weather predictors but feels that global warming is a hoax.

Human Influence. A second school of thought claims that the burning of coal and other fossil fuels has released enormous amounts of carbon dioxide gas into the atmosphere, causing a warming trend since 1860. Not only has the atmosphere heated up, but also so has the land surface and surface water temperatures of the oceans. It's the increased surface water temperatures that have interested climate scientists who study hurricanes because hurricanes "feed" or get their energy from warm ocean water. Increase the water temperature, and you have provided additional energy resulting in increased numbers and more intense hurricanes, they say.



Research done at Georgia Institute of Technology and reported elsewhere supports the second claim. Studying hurricanes from the period 1970 to 2004, researchers found that the

number of category 4 and 5 hurricanes has more than doubled after 1990. This is shown in this graph.

Hurricane Katrina is an example of one of the most powerful hurricanes to affect the United States. After the hurricane, I developed a Katrina website as a resource for teachers to use help inform their students of hurricanes in general, and Katrina specifically.

The 2011 hurricane season has begun with tropical storm Arlene, and since Arlene, 2 hurricanes and 12 tropical storms have developed, and caused enormous damage to buildings, roads and bridges, and caused flooding in the Gulf Coast area, as well as in the Southeastern part of the U.S. extending north all the way to Vermont, and into Canada.

3.2. Climate Change: How the New Congress Will Help the Earth Get Hotter

When the new Congress convenes in January 2011, it will get hotter in the House & Senate with an influx of Representatives and Senators (all Republicans) who continue the conspiracy that global warming is a hoax, and that humans are not contributing to the warming of the Earth. This group of elected officials (especially in the House) will try and block any attempts at government projects and laws aimed at regulating carbon emissions, and other factors that are causing the earth to get hotter.

If you are teaching science, especially courses dealing with the environment, earth science, science teacher education, science-related social issues, then you will have an opportunity to involve your students in not only the scientific exploration of climate change, but how politics and "fossil-funded" organizations can influence public perception of scientific facts, and prevent the reduction of greenhouse gas emissions, and deflect any attempt at developing a national strategy of offset the effects of global warming.

On the website of the Center for American Progress, the authors give us a glimpse of the climate change that will blow into Washington, D.C.

Political Views of Global Warming

In January 2011, the 112th Congress will open session, with a huge contingent of Republicans who have explicitly rejected the threat of manmade global warming pollution. These climate zombies express the classic variants of global warming denial: that the planet is not warming, that cold weather refutes concerns about global warming, that man's influence is unclear, that climate scientists are engaged in a hoax, scam, or corrupt conspiracy, and that limiting greenhouse pollution would have no impact on global temperatures. Of special note are the conspiracy theorists that argue that hacked emails from climate scientists prove corruption, calling for kangaroo trials against practicing researchers.

If you click on the map shown below, it will bring to the "active" website where you can click on any state and find out how Congressional members think about climate change and global warming.

Click on the map which will take you to the map where you can investigate the climate change and global warming opinions of members of Congress

An interesting activity would be to have students find out what representatives from their state think about climate change, and why. How do these representatives explain the facts of temperature change, glacial melting, the rise of sea level, and the changes that occurring to biological systems around the earth?

3.3. Climate Change, Politics and Science Teaching

The new administration in Washington has made it clear that climate change would be one of the science-related issues that it would deal with, and there is clearly some evidence to support this. In an article in USA Today, entitled Politics heats up global warming suggested that climate scientists should get involved in the issue to help with our understanding of the science of climate change, and the implications for the earth, people and the economy. Climate change is also an important topic in science teaching, and many science teachers have approached the topic from a Science-Technology-Society (STS) approach.

New Report on Climate Change

A new report, Restructuring Federal Climate Research to Meet the Challenges of Climate Change, was released this week by the National Academy of Science and was written by the Committee on Strategic Advice on the U.S. Climate Change Science Program; National Research Council. You can download it here.

As pointed out in the report the US Climate Change Science Program is developing a new strategic plan for the new administration, and thus this report will play an important role in the development of this plan.

The report, which you can read using the links at the National Academies Press website as shown above, developed its report around a set of priorities. These priorities would be very useful concepts to help design a teaching strategy for climate change. Here are the priorities:

- Reorganize the program around integrated scientific-societal issues to facilitate cross- cutting research focused on understanding the interactions among the climate, human, and environmental systems and on supporting societal responses to climate change
- Establish a U.S. climate observing system, defined as including physical, biological, and social observations, to ensure that data needed to address climate change are collected or continued
- Develop the science base and infrastructure to support a new generation of coupled Earth system models to improve attribution and prediction of high impact regional weather and climate, to initialize seasonal to decadal climate forecasting, and to provide predictions of impacts affecting adaptive capacities and vulnerabilities of environmental and human systems
- Strengthen research on adaptation, mitigation, and vulnerability
- Initiate a national assessment process with broad stakeholder participation to determine the risks and costs of climate change impacts on the United States and to evaluate options for responding
- Coordinate federal efforts to provide climate services (scientific information, tools, and forecasts) routinely to decision makers

Greenhouse gas emissions, if continued at the present rate could lead to an increase of average global temperatures between 2 and 6 degrees, and there are some researchers who claim that the trend is continuing, and it doesn't appear to be abated. However, given the fact that the new U.S. Secretary of Energy, Stephen Chu advocates low emission fuels, wind and solar power, advanced biofuels, as well as an investment in upgrading the US electrical grid provide support that carbon emissions might be greatly reduced.

Resources

U.S. House Committee on Science and Technology

U.S. Senate Committee on Environment and Public Works

Science Education for Everyday Life: Evidence-Based Practice by Glen Aikenhead

Teaching Climate Change: Lessons from the past

EPA Climate Change Resources

Pew Center on Global Climate Change

3.4. Inspiring Your Students to Understand Climate-Change & Our Energy Future

Perhaps the most important role of a teacher is to inspire students to value their intellectual and emotional abilities and to understand how they can use science to "improve the lives of those they have touched and the differences they have made" (quote from Dr. Steven Chu's commencement speech at Caltech). It isn't enough to teach students to acquire scientific knowledge; we must find ways to help students use that knowledge in the service of others.

Teachers have been doing this for a long time. However, the importance of this role is diminished with the increasing attention placed on achievement test results, and standards-based curriculum.

Teachers, perhaps as much as anyone, are reminded every year what the future is about because they work with youth who have their future before them. Students look to their teachers for the understanding, knowledge and inspiration to acquire new tools to help them transition into adulthood.

I think that one of the most important aspects of teaching science, whether one is teaching physics, biology, chemistry or earth science, is to help students understand the dilemma we are in because of climate-change, AND to inspire them that science brings a sense of optimism in facing challenges, and that humans are capable of solving immense problems of this nature.

In a very recent speech, Secretary of Energy, Steven Chu noted what he called a remarkable scientific discovery:

For the first time in human history, science has told us that human activity is dramatically altering the destiny of our planet. Our carbon emissions since the beginning of the industrial revolution have caused the climate to change, and science is now projecting how our actions will affect the Earth fifty and a hundred years from now.

View of the Nature of Science

What I find appealing about Dr. Chu is his personal view on the nature of science, and how this view could be fundamental to the way and the purpose of teaching science. Here is what he said about naysayers who believe it is impossible to transition to a sustainable world of nine billion people where the standard of living of everyone is substantially elevated:

As a scientist, I refuse to accept this judgment. Scientists, if not optimistic by nature, have to be optimistic by natural selection in order to be successful. Without optimism, we would not have the audacity to believe we can go beyond the discoveries of the giants that went before us. Nor would we be willing to take on challenges where others have failed.

Chu is calling on America to lead a new industrial revolution that that will lay the foundation for a sustainable energy future. He informs us that energy efficiency and conservation will be central to our energy policy into the future, but that increased investment in alternative energies, nuclear power, nanotechnology, and bio-energy—all will play an important role.

If you are not familiar with Dr. Chu's ideas, I recommend that you read or watch his Caltech commencement speech. It's his kind of thinking that can lend enormous support to the nature of science teaching, and the role of "inspiration" as a vital aspect of professional science education.

Part 4. Volcanic Eruptions
4.1. Iceland's Volcanic Activity

Eyjafjallajokull, the volcano in Iceland that has been erupting and causing havoc for thousands of people around the world, is one of about 200 volcanoes that are located in Iceland. Iceland is the world's most active volcanic area, and the country is located at the interface of two tectonic plates that are moving away from each other at a point known as the mid-ocean ridge. Iceland is unique that the spreading apart of the these two large tectonic plates is taking place at sea level, as opposed to many other examples of spreading that occur well below sea level.

Here are some pictures that I've gathered to include images of the volcano, as well as maps of the geology of the Iceland.

This map identifies two of Iceland's prominent geological features: glaciers and volcanoes. Source: http://www.exploratorium.edu/theworld/iceland/map.html

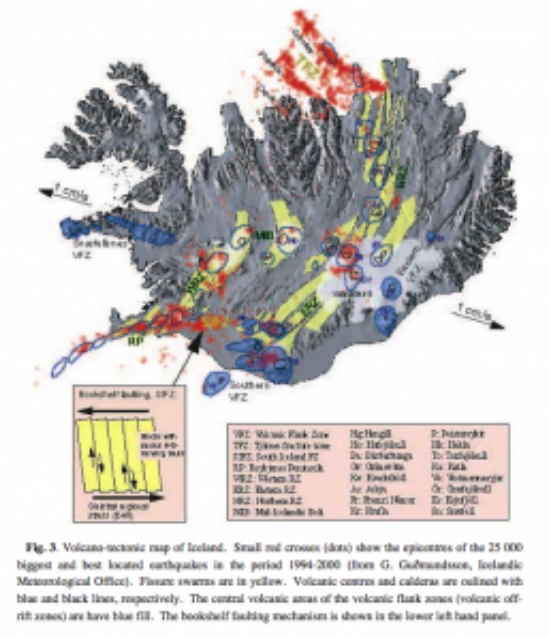


Fig. 3. Volcano-tectonic map of Iceland. Small red crosses (dots) show the epicentres of the 25 000 biggest and best located earthquakes in the period 1994-2000 (from G. Guðmundsson, Icelandic Meteorological Office). Fissure swarms are in yellow. Volcanic centres and calderas are outlined with blue and black lines, respectively. The central volcanic areas of the volcanic flank zones (volcanic off-rift zones) are have blue fill. The bookshelf faulting mechanism is shown in the lower left hand panel.

This map provides more detail about the nature of Iceland's volcanoes, and geological activity on the island. Source: usgs.gov

4.2. Volcano in Your Backyard

Volcanoes have received a bad rap recently, especially if the US Geological Survey is to receive “stimulus” funding to monitor and investigate volcanoes. According to the Governor of Louisiana funding “something called ‘volcano monitoring‘ is an example of questionable funding in the appropriation bill.

But the mayor of Vancouver, Washington begs to differ, and points out to the Governor of Louisiana that our volcano is active, and still rumbles, and indeed they would want the USGS to be on the watch.

Actually the USGS is involved in many important monitoring activities including volcanoes, earthquakes, droughts, floods, wildfires, and others. Perhaps it needs even more funding.

Several years ago on of my graduate students (DeAnn Peterson) designed an amazing unit of teaching entitled “What if you had a volcano in your backyard?” Her idea was to create a context for an inquiry project that was based on lived-experiences.

Here is her rationale for this investigation:

Science education in this modern world of high information availability must be an inquiry-based exercise. Science, itself, must be defined as a verb, an action, and a method of looking at the world. And when the world, with all of its uniqueness and exceptions to the "rules" is readily available through the Internet, simple memorization of facts can become useless. Student must use their brainpower for finding the threads that connect and related all things. In this study of volcanoes, the Mt. St. Helen's example is used to show the power and the magnitude of a volcano; the devastation of all forms of life that occur following a blast.

The lesson intent is to explore how a volcano affects more than just geology of the area. The example is used to show how life in a devastated area reforms and rejuvenates. The students are invited to put themselves into the vicinity of a modern day active volcano and discover how their life and their world around them might change. Even though this is intended as an earth science unit, the interconnectedness of the threads that connect all things are woven together by teaching geography, geology, chemistry, biology, weather, history, and even social studies just by studying a volcano.

Not only should volcanoes be monitored by the USGS, but also they provide a powerful context to design a teaching unit based on real events that effect real people. Peterson understood this, and developed a powerful unit of teaching. Perhaps the misconception that the Governor has about the value of monitoring natural disasters can be a lesson underscoring the challenge that we have as science teachers.

4.3. From Volcanoes in Your Backyard to Snow in Moscow and in My Backyard

About a week ago, I wrote a post entitled Volcano in Your Backyard, which was initiated by the Governor of Louisiana's comment that spending money on volcano monitoring was an other example of wasteful spending by the government.

February 8, 1984, I was on board a Delta Airlines flight from Atlanta to Portland, and as we approached the region, I was able to take this picture of Mount St. Helens during its activity in the early 1980s. You can view the volcano today by linking to the Mount St. Helens Volcanocams located on the Johnston Ridge Observatory.

Lousiana

There is no doubt that Governor Jindal was unaware of the USGS Volcano Hazards Program; indeed if he had, he wouldn't have stuck his foot in his mouth. It amazes me that any governor would make such a claim disparaging important monitoring programs, but especially the Governor of Louisiana, a state which has been ravished by hurricanes. He ought to be aware that we fund the National, a monitoring program that has unfortunately become more important to us in the past five years.

Atlanta

It is March 1, and in Atlanta as well as much of the Southeast, it is snowing.

Meteorologists predicted this storm, and their monitoring efforts certainly play an important role in our lives. Living in Atlanta, we have our share of thunderstorms, and tornadoes and the monitoring effort of meteorologists is extremely important, and people come to expect a high degree of accuracy.

Moscow

In April 1998, as Director of the Global Thinking Project, I was part of a large delegation of American middle and high school students and their teachers participating in a conference in Moscow, Russia.

We had just finished a three-week exchange period during which time Russian students and their teachers had hosted the Americans. The students were involved in an exchange project that focused on environmental science as part of the GTP. April in Moscow is a lovely period of time to be there, and to enjoy the Moscow Spring. More than 100 Americans and Russians were staying at the Ukraine Hotel in Moscow having arrived there on April 13 for a four-day conference that was held nearby at School 710. On April 14th, the heaviest mid-April snowstorm in more than 100 years fell on Moscow.

All of the participants in the GTP conference enjoyed the surprise snowstorm, except for the mayor of Moscow. According to the major's office, cars were stuck in slush, trees were down, and the huge fleet of snowplows still could not get the city out of gridlock. Because of the lack of warning, the major decided to terminate the contract of the federal weather service that provided weather reports, and set up its own weather service.

The GTP conferenced was not deterred by the snowstorm. We walked to School 710 each day, and by the time of the conference, the roads had cleared, and we were able to order a lunch each day for 125 participants from Moscow's first McDonalds.

Part 5. Earthquakes
5.1. The Earthquake of 1906 and the New Geology

I am in the mood to write about earthquakes. I've written about them before, and designed activities for teachers and high school students years ago. I have only experienced three earthquakes (in Columbus, Ohio (1967), San Francisco (1985) and Seattle (2001)). In the fact the last one was a very powerful quake that rocked the Pacific Northwest. I was doing a seminar with about 100 teachers, and we had to seek shelter underneath desks in the conference room. It was a riveting experience, but it was not at all close to the experience of the earthquake that occurred further south many years earlier.

1906 San Francisco Earthquake

100 years ago this April 16th, one of the largest earthquakes along the edge of the North American and Pacific Plates occurred near Daly City (the epicenter of the Great San Francisco Earthquake). In a new book (A Crack in the Edge of the World) author Simon Winchester explores not only the San Francisco earthquake, but also the emergence of the new geology embodied in the Theory of Plate Tectonics.

Winchester opens our eyes to the significance of the earthquake in the emergence of geology in the United States, but also helps us understand the nature of the movement along the San Andreas Fault (SAF), and the unusual character of the geology in the American West. Winchester talks briefly about J. Tuzo Wilson, the Canadian geologist, who in the 1960?s was giving talks and writing papers on the new theory. I was a graduate student in the late 1960?s at Ohio State University, and Wilson was on leave visiting the geology department at OSU. I was fortunate to take one of his seminars and be introduced to this new theory.

Plate Tectonics

It wasn't until 1970?s that many papers were written that led credence to support the Theory of Plate Tectonics. Winchester takes us on a riveting story about the earth's geology and brings us back to pre-Pangaea time and the identification of ancient continents including UR, Arctica, Baltica and Atlantica. This is great reading, as are Winchester's other books (for example Krakatoa and The Map That Changed the World).

Most earthquakes occur along the edges of crustal plates, but they occur elsewhere as well. Powerful earthquakes occur in places that are far from the edges of crustal plates, such as Charleston, SC, New Madrid, MO, or New England. The August 2011 earthquake centered in Virginia is a good example. The quakes that occurred in these locations were high magnitude ones, and occurred along faults that have moved in the past, and could (unpredictably) shake in the future. Winchester discusses the possibility that the North American Plate (which extends from Iceland to California), might be splitting apart and separating along a fault running north to south in the New Madrid area!

If you are teaching about earthquakes, volcanoes and plate tectonics, I do recommend Winchester's book to

you. You might also check out the USGS site on teaching about earthquakes.

5.2. 1906 San Francsico Earthquake Centennial

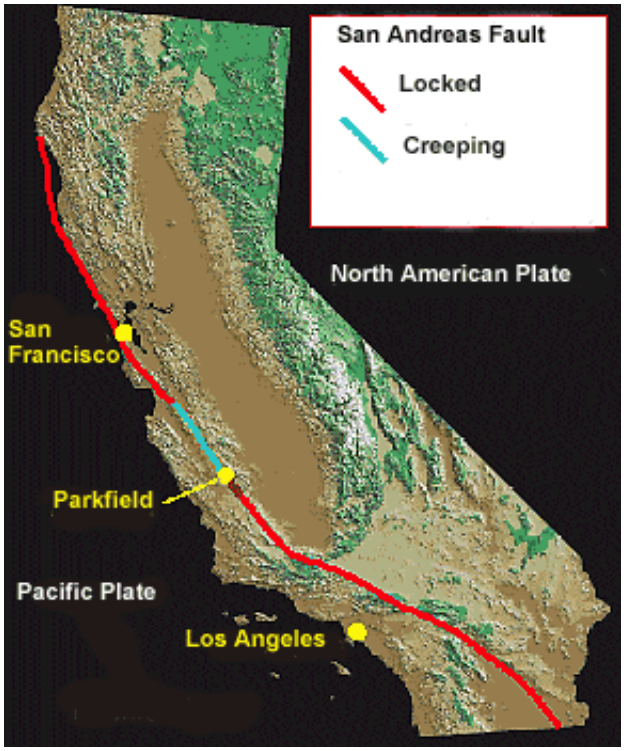
Today marks the 100th anniversary of the 1906 San Francisco earthquake which hit the city at 5.12 a.m. on that day. In an earlier post, I commented on the significance of the 1906 earthquake, and recommended a book by Simon Winchester, A Crack in the Edge of the World: America and the Great California Earthquake of 1906. Winchester's book tells the story of the "new geology" and helps us understand the cause of the earthquake (and all earthquakes), and provides a deeper understanding of the earth.

The city of San Francisco set up a web site marking the earthquake, and also held a huge gathering in the financial district.

The 7.8 Earthquake in 1906

The 7.8 magnitude earthquake literally destroyed the city, and the great fire that followed reeked devastating damage of the city for days after. The earthquake is considered one of the worst disasters to hit the U.S. with more than 3,000 people killed, more than 20,000 buildings destroyed (see image of city hall below), and it took until 1915 to re-build the city. This seems like very timely information for the rebuilding of New Orleans.

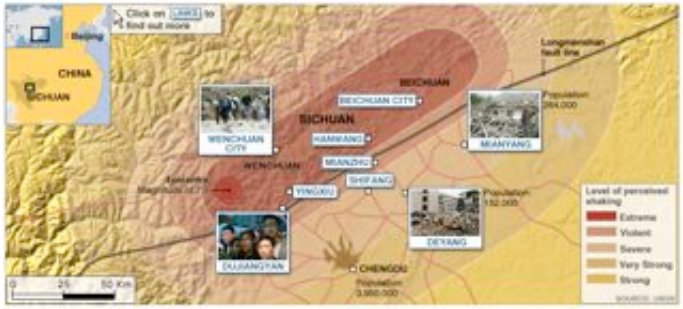
The quake was caused by a rupture (of more than 300 miles) along the San Andreas Fault, which separates two huge crustal plates: the North American Plate and the Pacific Plate.



These two masses of rocks rub up against each other along the San Andreas Fault, and at times, the build up of stress is released when the plates move, causing an earthquake.

5.3. Impact and Cause of China's Sichuan Earthquake

The Sichuan earthquake that occurred in China was, according to geologists, a two-stage quake, with the total duration of about 2 minutes. According to geologists at Tsukuba University, the quake was movement along the Longmenshan Fault that moved earth in two sections. Geologists report that because the quake was a shallow one (about 6 miles beneath the surface), it had a greater effect on the area near the epicenter, which, as we know, is highly populated.



Map of the Sichuan earthquake. Source: BBC news

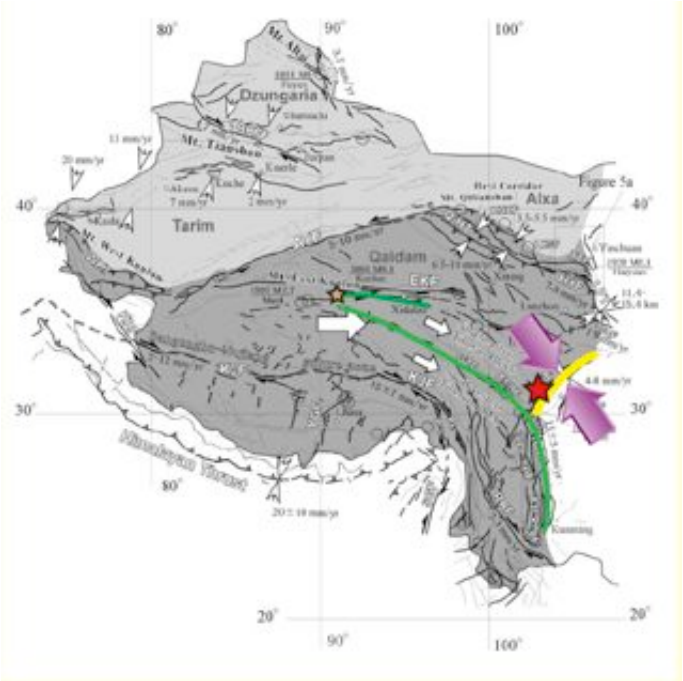
The quake was devastating. The map below shows some of the communities that were heavily damaged. You can go to this site, and click on the individual communities to read about the earthquake.

Impact on People

This was a quake that had two strong tremors, and caused utter destruction in some areas of the Sichuan Province. NBC news showed a video obtained from a British TV network showing these eventful two minutes. The scenes are a powerful depiction of what happens to people caught in an earthquake of this magnitude.

Cause of the Quake

The quake was caused by movement along a thrust fault located on Longmenshan Fault (yellow line). The deformation of the rocks in this region was caused by the collision between the Indian and Eurasian tectonic (crustal) plates and the continued movement of the plates relative to each other. The Sichuan Province is a very active tectonic area, as is the entire West Coast of the United States.



This map shows the tectonics in the Sichuan Province, and in particular the Longmenshan thrust fault and the epicenter of the earthquake (red star). The Source: He and Tsukada

5.4. The Severity of the Haitian Earthquake

The earthquake that occurred near Port-au-Prince, Haiti on January 12, 2010 was one of the worst ever-natural disasters. Aid is pouring into the Haitian capital, and aid organizations, and governments from around the world are descending on this Caribbean country. Our hearts go out to the people in Haiti, and we only hope that the aid that is streaming there, and on the ground will reach the people who so desperately need it.

In this post, I am going to talk about the nature of the Haitian earthquake, and what we know about predicting and preparing for earthquakes. We know a lot, but we still cannot predict earthquakes. Here is some information in light of this tragedy in Haiti.

Enriquillo-Plantain Garden Fault

Roger Musson, a British Geological Survey geologist spoke with Eban Harrell who reported his remarks in a *Time*online report. According to Musson, the earthquake that happened on Tuesday was what geologists call a strike-slip (or transform) earthquake where one side of fault slides horizontally past the other side.

Diagram of a strike-slip fault, similar to the fault system in Haiti

Musson identified the fault as the Enriquillo-Plantain Garden fault, and it analogous to the San Andreas Fault in that this type of fault is the boundary between two crustal plates. As Musson points out, this was the “big one” for this fault in that the previous very large quake here was nearly 200 years ago. In his opinion, the pressure along this fault system has shifted to the West, and he expects another large earthquake in 20 – 40

years in Haiti or Jamaica. He also thinks that the aftershocks will dissipate over the coming days.

Predicting Earthquakes

Can earthquakes be predicted? Could this one in Haiti been predicted. As I said above, the fault system within which the Haitian earthquake happened is analogous to the San Andreas Fault that separates the western edge of the North American Plate from the eastern edge of the Pacific Plate. According to geologists, the Enriquillo-Plantain Garden Fault are studied and monitored to the same degree that geologists have been monitoring and studying the San Andreas Fault in California.

Over long periods of time, 20, 40, 80, 100, 200 years, geologists can say that one could expect an earthquake along a particular fault system. In the case of Haiti, geologists have been predicting that a large earthquake could occur along the boundary between the Caribbean and the North American plate. Earthquakes cannot be forecast the way we can forecast a tornado or a thunderstorm, or even a volcanic eruption. Earthquakes go undetected until they happen.

Yet, geologists know a lot about the fault zones here in the Caribbean, and can make general statements about the hazards associated with a fault zone. But still, we are unable to say that an earthquake will happen at a particular time.

Preparing for Earthquakes

The only thing we can do is to prepare for an earthquake. The U.S. Geological Survey has an earthquake hazards program and website that is valuable and would be useful to you in sharing and teaching your students about earthquakes.

The extent of the destruction of the buildings in Port-Au-Prince and the cities and towns near indicate the lack of earthquake-resistant construction. Haiti, which is one of the poorest countries in the Western Hemisphere, has not had the financial resources to undertake a comprehensive approach to earthquake-resistant construction. You might recall that the 2008 Sichuan earthquake destroyed thousands of buildings, many of which were schools. Later inspection revealed that most of these schools were built without consideration of earthquakes, and the result was utter disaster, and the death of more than 10,000 school children.

Masonry building destroyed in the Port-Au-Prince

A valuable resource in helping us understand the cause and sources of earthquake damage is National Information Service for Earthquake Engineering. In the case of the earthquake in Haiti, many of the buildings were constructed of unreinforced masonry, which according to engineering geologists is extremely susceptible to damage during an earthquake. The loss of buildings in this city was catastrophic as is evidenced by the pictures we all see on television and on the Internet.

The Destructive Power of Earthquakes

The Haitian earthquake was huge, and because it occurred near a major metropolitan area, several million people have been affected by the quake. Some estimates put the number at 3 million people. In the context of other significant earthquakes, the Haitian earthquake is one of the worst.

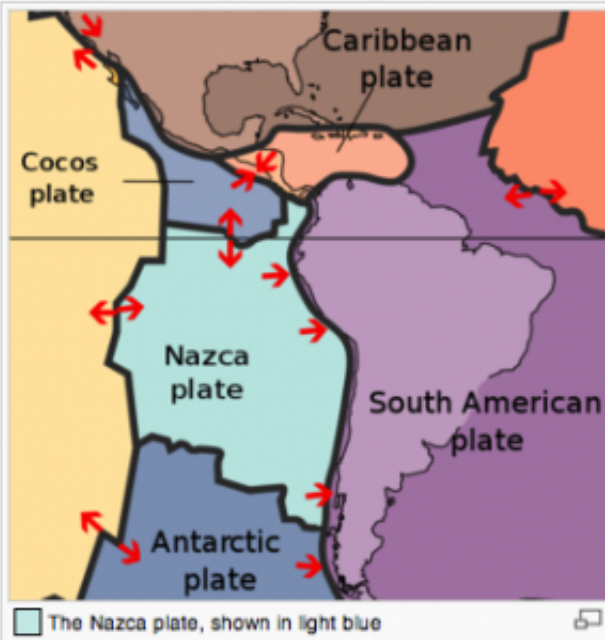
Here is a list of the ten most destructive earthquakes compiled by the editors of Time.

1. 1556: Shaanxi, China
2. 1976: Tangshan, China
3. 2004: Indian Ocean Tsunami
4. 1920: Haiyuan, China
5. 1923: Kanto, Japan
6. 1948: Turkmenistan
7. 2008: Sichuan Province, China
8. 2005: Kashmir, Pakistan
9. 1908: Messina, Italy
10. 1970: Chimbote, Peru

5.5. Magnitude 8.8 Chile Earthquake

In the book, The Art of Teaching Science, Chile is one the countries featured in an exploration of science education around the world. Claudia Rose, Director of the International Baccalaureate Program at the International School Nido de Aguilas in Santiago, wrote the article. As of this writing, I was unable to access any of the links to the school, and I am sure that the magnitude 8.8 earthquake off the coast near Santiago is reason for the lack of connectivity to the school's server. Naturally, we are concerned, and will attempt further contact with the school.

The magnitude 8.8 Chile earthquake which occurred on February 27, 2010 was the result of movement between the Nazca and South American tectonic plates. The Nazca plate, shown here, is an oceanic tectonic plate off the west coast of South America. The Nazca plate is undergoing subduction moving under the South American Plate along the Peru-Chile Trench.



Location of Nazca tectonic plate sandwiched between the Pacific, Antarctic, and South American tectonic plates

In 1960, the largest quake (magnitude 9.5) ever recorded off the coast of Chile. The result of this quake was the rebuilding of Chile using very strict earthquake building standards. Even with these standards, the devastation of the February 27-8.8 quake is immense, especially in the city of Concepción, Chile's second

largest city, and located only 70 miles from the epicenter of the quake (Santiago is 200 miles from the epicenter).

As seen on news reports on TV and Internet reports, the devastation in Chile is huge, and the latest reports place the death toll at over 700 people. Roads, buildings, and the general infrastructure have been damaged, and in many cases destroyed. International aid is beginning, but the toll on the people of Chile is severe, and our hearts go out to them.

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Omne tulit punctum qui miscuit utile dulci — Horace