The Case for Climate Literacy in the 21st Century

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ABSTRACT

The advent of the Internet and evolutionary advances in geospatial data browsers, virtual globes, and immersive visualization displays have significantly increased the potential for a more climate science literate public. In the same time, space-based Earth-observing agencies like NASA and NOAA have geometrically increased the volume of data they collect everyday, over the entire globe. Fortunately, Moore's Law held true during that same time span so that the processing capacity of modern computers enabled scientists to collect, process, and share these data with increasing efficiency and turn-around time. In just the last two decades the combination of these technologies has substantially increased public access to cutting-edge climate science data and information. But has there been a corresponding increase in public climate science literacy? And, if so, has there also been a corresponding increase in positive public attitudes and opinions about climate science research? In this paper we review some current research about the public's awareness, understanding, and opinions about current climate research. We review some initiatives that our agencies have taken to help improve climate science literacy. Our own research, and others', suggests it is possible to improve climate science literacy and positive attitudes about modern climate research, given the use of particular methods of communication. We conclude with a call for collaborators to work with NASA and NOAA in the assembly of a "synergetic" new climate science communications and education infrastructure, as articulated by the late Buckminster Fuller, in which the whole works together much more effectively than the sum of the individual parts. We argue that the inherent difficulty of improving public climate science literacy, much less addressing the problems that stem from illiteracy and negative attitudes toward the science, render the problem too great for any one agency or effort to tackle alone. Attacking the problem synergistically increases the potential for success while enriching all who are involved in the collaborative effort.

INTRODUCTION

"The consequences of various world plans could be computed and projected, using the accumulated history-long inventory of economic, demographic, and sociological data. All the world would be dynamically viewable and picturable and radioable to all the world, so that common consideration in a most educated manner of all world problems by all world people would become a practical event."

— R. Buckminster Fuller,
in *Education Automation*, 1962

Before the advent of the Internet, R. Buckminster Fuller foresaw a convergence of technologies, data, and applications that would one day afford all citizens of the world a virtually unlimited ability to summon information about any time and place in the world. The interface, he said, could be conceived as a "Geoscope"—a large network of Earth-shaped displays that would vividly display real-time global data, or perhaps animate to show changes over time. "With the Geoscope," Fuller explained, "humanity would be able to recognize formerly invisible patterns and thereby to forecast and plan in vastly greater magnitude than heretofore." In Fuller's view, such sophisticated technology would grant users easy access to complex datasets together with analytic tools that would readily yield deeper insights and understanding. By helping the world's citizens and decision makers to literally *see* megatrends occurring on our world — and their interconnected causes and effects — Fuller hoped the Geoscope, actively deployed within the framework of his "World Game," would encourage comprehensive and anticipatory understanding of how to make the world work more effectively for "100 percent of humanity in the shortest possible time without ecological offense or the disadvantage of anyone" (Fuller, 1981).

What might have seemed farfetched to anyone reading Fuller's words 45 years ago today seems imminent. Over the past two decades climate research agencies like NASA and NOAA have collected and published petabytes (quadrillions of bytes) of freely available (and low-cost) data sets quantifying a wide variety of our world's biological, geological, chemical, and physical parameters. Fortunately, Moore's Law held true during that same time span so that there was a parallel increase in the computational capacity required to collect, process, and share these data with increasing efficiency. Likewise, to help scientists and non-scientists more effectively tap into this wealth of data, a new generation of geospatial data browsers (henceforth "geobrowsers") and other computer tools exists today enabling users, via the Internet, to freely (or, in some cases, at low-cost) and almost instantaneously summon and display datasets allowing them to visualize and understand ongoing changes in weather, climate, land and ocean surface features, atmospheric chemistry, etc. There are also biological, economic, and socio-political datasets readily available such as epidemiological vectors, population density and poverty indicators, etc. Decision support system managers increasingly rely upon such data to serve society by forecasting climate impacts on both regional and global agricultural markets, correlating economic trends with environmental health in developing countries, identifying and mitigating risk from natural hazards, devising new ways to stimulate commerce through new technologies, and a myriad of other ways.

Over the past decade, "virtual globe" visualization platforms reminiscent of, or directly inspired by, Fuller's Geoscope have been developed, including *Google Earth*, NASA's *WorldWind*, *GeoFusion*, ESRI's *ArcGIS Explorer*, *EarthSLOT*, and others. While the popularity of these browsers is rapidly increasing, their numerous application areas are only just beginning to be realized. Similarly, internally and externally light-projected digital globe displays, like NOAA's Science on a Sphere, are installed in numerous science centers around the country. Furthermore, a global network of portable and permanent "fulldome" theaters continues to expand, able to project a broad range of computer-generated simulations beyond the strict astronomical themes of their planetarium predecessors. By projecting large-scale visualizations of local and global geospatial data onto spherical surfaces, these technologies serve as "attention-grabbers" to facilitate dialogues about climate science topics. In short, today's combination of data resources, computing technologies, geobrowsers, virtual globes, and immersive display technologies can be used to provide experiential data-driven decision support and scenario development tools reminiscent of Fuller's vision: "All the world data would be dynamically viewable and picturable and relayable by radio to all the world, so that common consideration in a most educated manner of all world problems by all world people would become a practical everyday, -hour, and -minute event" (Fuller, 1981).

But what has been the effect of all the aforementioned technological progress on the climate science literacy of non-scientists? One might assume that such progress would inevitably have lead to citizens and policy makers who have a much more detailed understanding of Earth's climate system than they did, say, two decades ago. One might further assume that such progress would produce greater confidence in climate scientists among non-scientists. Today, climate scientists have the capacity to ask and answer complex and critical questions about how our world works that would astonish climate scientists of just one generation ago. Moreover, they can do so in a tiny fraction of the time it took their counterparts of yesteryear, and then they can demonstrate to the public that they have done so with unprecedented clarity, using the aforementioned data visualization tools. Thus, one might assume non-scientists' attitudes—including the trust, credibility, and positive feelings—toward climate researchers would have improved. Yet our research as well as research by social scientists reveals that the understanding and perceptions today among non-scientists is mixed, at best. Why? And perhaps more importantly, how can we better use our modern suite of data visualization tools to improve the public's literacy and attitudes about climate science?

Today's climate literacy crisis

Since 1997 social scientist Jon Krosnick, of Stanford University, has tracked Americans' awareness, understanding, and opinions about global warming through periodic random surveys. Between 1997 and 2006, he observed a steady increase in public concern about the issue, which spiked sharply upward between 2005-06. He reported, "A vast majority, 85 percent, believes global warming probably is occurring, up slightly from 80 percent in a 1998 poll. But fewer than four in 10 are very sure of it, a level of uncertainty that reflects broad and continued belief that scientists themselves disagree on whether or not it's happening." He notes that, in 2006, 64 percent of Americans perceived "a lot of disagreement" among scientists about whether global warming is happening (Krosnick, 2006). Krosnick's findings are independently supported by Georgetown University Professor Thomas Brewer, who synthesized the results from a variety of surveys conducted between 1989 and 2006 (by ABC/Washington Post, Gallup, ORCA, PIPA, and PPIC) to measure public awareness, understanding and opinions about climate change. Collectively those surveys reveal a consensus among Americans that global warming is happening, and that they are worried a "great deal" or "fair amount" about it (Brewer, 2006). And yet Brewer too notes that there is a disparity between Americans' concerns about global warming and their perceptions of uncertainty and disagreement among climate scientists.

In fact, there is no such disagreement among climate scientists. We recognize and acknowledge that there is always some uncertainty in all branches of science, including climatology, among even the most well established theories. We assert that, in scientific terms, "uncertainty" is not the same thing as "doubt"; nor is uncertainty, by itself, a cause for disagreement. Earth's average temperature has risen by at least 0.5°C over the last century, climate modelers predict the globe will continue warming through the course of the 21st century, and human emissions of greenhouse gases are major cause of the warming trend—each of these statements are empirically observed, reproducible facts that are not questioned the peer-reviewed climate science literature (IPCC 2007). Where does this mistaken public perception come from? Considering most Americans get most of their science information from TV news and other news media, could such news media inadvertently be misleading the public?

Communications research shows that the quality and style of news reporting significantly influences readers' / listeners' understanding and perceptions about global warming (Corbett and Durfee, 2004). Journalists are trained to "balance" their reports by presenting both (or all) sides of a given issue. Though noble in its original intent, this practice, ironically, sometimes introduces the potential for *bias* in reports about climate change research. A recent review of the climate science literature reveals no evidence of controversy among climate scientists about whether the globe has warmed by at least 0.5°C in the last century, nor whether humans are substantial reason for the warming due to the increase in greenhouse gas emissions (Boykoff and Boykoff, 2004). Whereas there may be little or no disagreement among the science community about the fact that the globe is warming and humans are largely the cause of it, journalists continue to seek out dissenting or alternative views to preserve their notion (or at least the appearance of) balance in their reports. Such journalistic practice tends to distort climate science in the minds of non-scientists by fomenting the false impression that there is more uncertainty among scientists than there really is (Corbett and Durfee, 2004). And worse, such journalistic practice lends a disproportionate voice in the mass media to lobbyists and policy analysts who may be more interested in advocating or defending a given political, social, or commercial agenda than educating the public about climate science. "Reality must take precedence over public relations," the late, great physicist Richard Feynman once observed, "for nature cannot be fooled" (Feynman, 1986).

On climate science literacy and why it matters

Generally speaking, "science literate" people have a basic understanding of how biological, chemical, geological, and physical systems work in the natural world. Such people understand the nature of science and scientific inquiry, they understand the processes and methods for gathering the knowledge, and thus they have some ability to assess the validity and relevance of scientific information. However, since no one can know everything, who is to say what set of facts a person needs to know to be deemed truly “science literate”? We acknowledge and commend AAAS Project 2061, which has published a detailed definition and learning progression maps of what citizens should know in order to be science literate (AAAS, 2007)

The late Jean Mayer once opined that science literacy isn’t a measure of what one knows, but rather is a measure of one’s skill at gathering information about a given subject together with one’s ability to distinguish credible from non-credible sources. Not everyone is concerned with promoting science literacy; there are many agendas driven by social, political, and commercial interests and therefore “spin” abounds. This fact carries serious implications for the quantity and quality of the information available via the Internet today. Given that the Internet places exponentially greater information at the public's fingertips than was previously available, ‘discernment of credible sources’ is an essential skill for the science literate person.

We believe that science literacy matters because science and democracy go hand in hand. Science engenders democracy by evolving how people think, and by enhancing how they interact (Kuhn, 2003). Science is a uniquely human endeavor (as far as we know) which promises to improve our understanding of the natural world and, hopefully, to improve our quality of life. The public, therefore, has a say in whether and what science will be supported using public tax dollars, and whether and how the fruits of science should be integrated into society in applied ways. The more scientifically literate the citizens, the likelier they are to understand news reports about a given science subject, to effectively participate in public dialogues about that subject, and to vote according to their views regarding science policy decisions. “Climate science literacy” in particular, requires citizens to understand three basic concepts: (1) climate scientists operate under the assumption that Earth’s climate system is understandable, and therefore predictable; (2) the field of climatology is progressive and cumulative, and understanding of Earth's climate system is still evolving; and (3) climate scientists rely upon empirical evidence—which can be reproduced and validated through peer review.

That said, one should never assume there’s a positive correlation between understanding and positive attitudes about a given science policy. Knowledge is not a strong predictor of pro or con attitudes about science policy. There is little evidence that mediated science communication has any effect at all on adult science literacy (Borchelt, 2002). Likewise, one should never assume a positive correlation between favorable public opinion and a desired science policy decision. In the United States, science policy is set by members of the Executive and Legislative Branches—usually guided and informed by senior or prominent members of the science community—and there is typically no wider public participation in the process (Miller, 2004). To put it bluntly, decision makers rarely (if ever) consult popular public opinion polls when discussing and deciding science policy. President John F. Kennedy’s historic call to put a human on the moon is a case in point. Kennedy’s commitment was made and, subsequently, the Congress allocated dollars for the mission even though popular opinion polls throughout the 1960s showed that a majority of Americans were *opposed* to sending a human to the moon because they thought it was too costly (Launius, 2003).

However, one should not conclude that public understanding and public opinion are irrelevant to science policy. When policy leaders do not agree on how to resolve a given science issue, their debates and disagreements will excite the attention of journalists, thereby giving increased exposure to the issue among mainstream media. In such cases, policy leaders also often appeal to their “science attentive publics” to get involved by voicing their opinions to their government representatives and in public forums (Miller, 2004). Research shows that roughly 40 million American adults are “science attentive” and roughly 12 million are “space attentive”—meaning they are very interested in public policy pertaining to these subjects, they believe themselves to be very well informed about these subjects, and they regularly seek information about them (Miller, 2004). Thus, government leaders' public appeals for support and concurrence from members of this community are more likely to elicit some response than, say, from among members of the "residual public"— those who are interested and/or unaware of the issue. But if/when policy leaders debate possible actions about global warming, what will be the response from the public? Is the public sufficiently well informed? What determines whether the public will support or oppose a given climate science policy?

Jon Krosnick stated, "People who think scientists agree on the issue are much more apt to see it as a very serious problem, to call it important personally, to believe it's mainly caused by human activity, to think it can be addressed, and to say the government should do more (indeed, much more) about it" (Krosnick, 2007). This point is particularly important given the Intergovernmental Panel on Climate Change's (IPCC) Fourth assessment:

> "Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture. … The understanding of anthropogenic warming and cooling influences on climate has improved … leading to a very high confidence (90 percent) that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 Wm^{-2}." (IPCC 2007)

In its subsequent assessment on the likely impacts of global warming, the IPCC summarizes observational evidence that all continents and most oceans are being affected by regional climate changes and, particularly, temperature increases. Glaciers and ice sheets are melting, Arctic and Antarctic biomes are being impacted, water quality of lakes and rivers is affected, Spring arrives earlier bringing shifts in plant senescence and flower time as well as the potential to disrupt the patterns of migratory species. In short, the IPCC report states, "it is likely (66 to 90 percent probability) that anthropogenic warming has had a discernible influence on many physical and biological systems." These disturbing reports by the IPCC point to a clear need to hold substantial policy relevant dialogues about the causes and effects of global warming, and what, if anything, should be done about them. The IPCC does not mince words on this point: "Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions" (IPCC 2007).

Climate scientists are clear and unambiguous in their assessments of the problem, the likely impacts, and what must be done about it. But do non-scientists see it the same way? The answer to this question contains good news and some bad news: while public understanding of global warming is increasing at an unprecedented rate, the seriousness that the public places on the issue is disproportionately low. What accounts for this seeming disparity? Krosnick posits that "beliefs about whether global warming is a problem are a function of relevant personal experiences (with the weather) and messages from informants (in this case, scientists), whereas attitudes toward global warming are a function of particular perceived consequences of global warming, and that certainty about these attitudes and beliefs is a function of knowledge and prior thought" (Krosnick et al., 2006). Given the scale of mitigation and adaptation strategies that are being debated, Krosnick's findings underscore the need for a well-informed public — particularly policy leaders and decision makers — is essential. To convey the complexities of Earth's climate system requires a robust communications strategy that is flexible enough to inform the decisions policy makers will need to make, while allowing citizens to interact with the data and to investigate the science in forums and in formats with which they are comfortable. Emphasis should be placed on informing and guiding non-scientists in *how* to think scientifically; not on telling them *what* to think. We present some recommended strategies for doing so in the following sections that climate science research agencies in particular should consider adopting.

Many audiences, many levels of engagement

In an ideal world, there would be one obvious method for communicating science results to all people, scientists and non-scientists alike. Alas, not all people are equal in their capacity to understand scientific information. There are many different audience and therefore there are many different information-seeking behaviors. Moreover, every individual comes with personal predispositions and political biases that make them more or less receptive to new scientific information. Thus, there is no one-size-fits-all science communications strategy. But of course agencies and organizations operating on limited resources must economize, balancing expense with efficiency and effectiveness. How can communicators succeed at such a complex task? Classifying non-scientists into categories that group individuals according to common characteristics, and then targeting each groups in decreasing order of priority, is one way to simplify the task.

However, critics of this strategy will argue that it smacks of elitism while running the risk of not serving parts of society on the basis of race, sex, income, social status, or some other such characteristic — each of which is unacceptable. Such an approach is hardly democratic, critics further point out, and the benefits of science literacy should be available to all Americans. Still, among government agencies like NASA and NOAA there remains the issue of limited budgets and the need to prioritize. To escape this conundrum, we recommend classifying all of society into groups, or strata, so that all parts of society are targeted but that the messages and methods of delivery are tailored differently for each group. For example, if the goal is to influence science policy, using a stratified model of society can be helpful in prioritizing audiences according to their relative contributions to determining science policy (Miller 2004). Another way is to characterize audiences according to their science information-seeking habits. This approach offers agencies like NASA and NOAA an ability to fine-tune their communications according to the variables that determine what is the most effective and efficient way to reach each target audience. The strategy is driven by audience needs, wants, and expectations for climate science information; by their capacity to understand it; and by how and where they seek it. The model is also useful in that it provides a framework for clarifying *why* (i.e., what we hope to accomplish) our agencies are trying to communicate with that stratum in addition to *what* we're trying to communicate.

Starting with the least influential public stratum and then moving up through the strata of increasing influence on science policy, our target audiences can be defined as follows (Miller, 2004):

1. "Uninterested and/or unaware"— (sometimes called "the residual public") referring to the portion of the public who don't know and/or don't care about climate science. This audience is the least likely to offer a return on investments in communicating with them, but we recognize that some fraction of this stratum has the potential to become interested in climate science and therefore efforts should be made to help them become interested in learning about the subject.
2. "Climate science interested"— referring to the portion of the public who are aware of climate science and who are open to learning more about it. This audience may yield some return on investment in efforts to communicate with them, but they are typically not attentive or engaged enough to exert any real influence on science policy. But we recognize that some fraction of this stratum has the potential to become Earth science attentive and therefore efforts should be made to help these people move up into the "attentive" stratum.
3. "Climate science attentive"— referring to the portion of the public who are active seekers and consumers of Earth science information, who consider themselves knowledgeable about the subject, and who are willing to participate in policy-relevant dialogue about it. This audience is likely to play a role in determining climate science policy, therefore investments should be made to augment their understanding of the subject. Plus, some fraction of this stratum has the potential to become more engaged in climate science and therefore efforts should be made to help these people to move up into the next stratum.

4. "Climate science engaged"— referring to citizen scientists and/or professionals who use the tools and data products from the Earth science community in applied ways for commercial (i.e. tourism, precision farming) or societal benefit (i.e. risk assessment and mitigation, decision support systems).

Of course these strata are already populated, so we know it is possible for individuals to move up through them. The question is: can we significantly *increase* the number of people who move up through these strata? If so, can we prove we did it? And if we can prove we did it, can we demonstrate how we did it and then quantify what is our overall potential for moving people up through these strata? We have some evidence that, yes, we can significantly increase the number of people who move up through these strata, and that, yes, we can prove we did it. We also have some evidence as to how we did it but, at present, quantifying our potential for doing so remains an outstanding problem. Our objective, methods, and supporting evidence, are presented in the following section.

The story of story and the Earth Observatory

There is ample evidence that providing science information to people within the context of a story enhances readers' / listeners' understanding of the information, their ability to create meaning from the new information they've received, and their ability to remember that information (Haven, 2005). Moreover, the human brain is wired to receive information in a story format (Bruner, 1998; Pinker, 2000). A story is often comprised of particular elements, including a protagonist (main character), a complicating factor or problem, a narrative about the protagonist's struggle to resolve the complication (thereby adding drama), sensory details about where and how the protagonist struggles in the narrative, and a resolution in which the protagonist overcomes the complication and reaches the goal. At their core, effective stories are often about *people.*

Thus stories can provide an effective way to overcome socio-political impedances and negative predispositions held by members of the "uninterested / unaware" and "interested" strata of the public by shifting focus away from scientific results or new inventions — which are abstract and not obviously relevant — and onto the scientists themselves. In other words, people may not be predisposed to caring if, say, ozone in the stratosphere over Antarctica is thinning, but they *are* predisposed to caring about other people (say, climate scientists for example) and, by association, why the protagonist in the story cares if there is a hole in the stratospheric ozone shield. Humans have an inherent readiness or predisposition to organize experience into story form: into viewpoints, characters, intentions, sequential plot structures, and the rest (Bruner, 1998). One hundred thousand years of evolutionary preference for, and reliance on, story has built into the human genetic code instructions to wire the brain to think in story terms by birth (Pinker, 2000). Conveying climate science information through stories provides an effective means of connecting with the public, potentially raising their awareness and exciting them into becoming interested in climate science. Moreover, by focusing on people doing things, such as climate scientists revealing the scientific method through narratives, emphasis is placed upon how and why climate science is done and not on its end results. Through this, audiences can learn how to think about the process of climate science instead of being told what to think about its outcomes. Because stories provide context and allow non-scientists to construct mental images of how and why climate scientists conduct their research — and how and why their methods led to their conclusions — the information is likelier to be perceived as credible and factual to non-scientists. In short, writes oceanographer and storyteller Kendall Haven, "Mental story maps are how humans make sense of other humans' behavior and create meaning from sensory input" (Haven, 2006).

Since it first published in April 1999, NASA's Earth Observatory (an on-line magazine about Earth system science, at earthobservatory.nasa.gov) has made climate science storytelling a central part of its focus. The site's "Features" section contains more than 200 climate-related stories about how NASA and NOAA scientists use remote-sensing data from NASA and NOAA satellites to advance understanding of Earth's climate system. Today, the site receives about 25,000 unique visitors per day from all over the world. What, if any, influence has the Earth Observatory's stories had on its readers? We solicited readers' feedback on three separate occasions over the last 8 years and have found evidence that the site has indeed elevated people from the "uninterested and/or unaware" stratum into the "climate science interested" stratum. Specific to "awareness raising," we presented the following statement to our visitors: "I did not know that NASA studies the Earth until I visited the Earth Observatory Web site," to which 27 percent of 2,033 public respondents agreed. We asked, "How easy or difficult is it to understand the writing on the Earth Observatory?" to which 52 percent of respondents selected "very easy" and another 37 percent chose "fairly easy." More interestingly, we presented the following statement in a later survey: "The Earth Observatory has made me want to learn more about Earth's environment or climate change," to which 39 percent of respondents "strongly agreed" and another 54 percent "agreed," out of 2,414 total respondents.

It's worth noting that 83 percent of the public respondents to our survey were 41 years old or older. More than half (53%) of these respondents have had no formal science coursework above the high school level. In terms of their level of comfort and satisfaction with the information published on the site, 98 percent of respondents said they were "highly likely" or "likely" to recommend the Earth Observatory as a source of Earth science information to a friend or colleague. When we asked how often they visit the site, 11 percent said "daily," 56 percent said "weekly," and 24 percent said "several times per month." Thus we have clear evidence that the context and content provided in the site, in a story format, is elevating individuals up the public continuum from "uninterested / unaware" into the "aware and interested" and even into the "attentive" strata. But what about the next step: going from "interested" and/or "attentive" up into the "engaged" stratum?

In two earlier surveys (2002 and 2004) we asked visitors: "If you had easy-to-use software and easy access to remote-sensing data, would you be interested in taking up Earth observation as a hobby?" Roughly two-thirds of our 1,996 respondents to this question said "yes," while about 30 percent said "maybe," and only 7 percent said "no." Moreover, in the open comments field we provided, we received a number of suggestions encouraging us to provide such resources along with an on-line guidebook of ideas and activities that would help hobbyists better understand what changes to look for in Earth's climate system, and how to make sense of them using the tools and data resources provided.

There are a range of professionals who are by definition "climate science attentive"—including students, formal and informal science educators, journalists and science writers, and even scientists in other fields of study. Our storytelling strategy has had a similarly positive effect among visitors from each of these domains. For example, we offered the following statement to the scientist respondents (86 percent of whom said they were not affiliated with the agency): "I enjoy the popular writing style on the Earth Observatory because it helps me to better understand science topics outside of my own discipline," to which 96 percent agreed (32% said "strongly agree"; 64% said "agree").

Among the 240 student respondents (98% of whom were in high school or higher), 22 percent said "the Earth Observatory has helped me to consider becoming a scientist"; 39 percent said the site "has made me more interested in taking science courses"; 37 percent said the site "has made my science courses more interesting"; and 73 percent said it "has added to my knowledge about topics I have studied in school." Moreover, we find that many students use the stories in Earth Observatory as the basis for their own school-related projects. Specifically, 38 percent said, "I've used [the site] as a resource for homework or project"; 47 percent said, "I visit the site to learn about Earth science related to my subject of study"; and 28 percent said, "I've used the site to find ideas for research projects or papers." Perhaps most gratifying, however, was the 71 percent who said they "visit the Earth Observatory for personal interest, not school related." Thus, there is evidence that the site is helping students to entertain science as a possible career path, to pursue higher degrees in science, and to cultivate a personal interest in the subject as well as academic.

Concluding call for a climate literacy coalition

Richard Feynman once said, "NASpA [and by extension, NOAA] owes it to the citizens from whom it asks support to be frank, honest, and informative, so that these citizens can make the wisest decisions for the use of their limited resources." We agree with Feynman's statement, and it is entirely commensurate with Buckminster Fuller's vision for the Geoscope. The evidence we have presented suggests that our effort to share our agencies' climate science research in both visual and story formats is successfully promoting climate science literacy among non-climate-scientists. Of course, more can and should be done. For example, replicating these stories and visualizations in other venues and using other media (in addition to the Internet) would help us dramatically broaden and amplify exposure to our climate science research among non-scientists.

We must guard against presenting global warming as overwhelming or unsolvable because people stop paying attention to a problem when they realize that there are no easy solutions for it (Krosnick, 2006). Moreover, people may judge as nationally serious only those problems about which they think action should and can be taken (Krosnick, 2006). These psychological insights into society point to a clear need to promote climate science literacy in the United States, given the current state of the climate system as documented by the IPCC. NOAA, NASA and EPA have assumed a leadership role in this area by working through the Climate Change Science Program's (CCSP) Communications Interagency Working Group (CIWG)—an interagency coordination effort. However, we wish to issue a call for a larger climate literacy effort that enables and fosters numerous partnerships, alliances and collaborations across the entire spectrum of educators, communicators, and science centers to achieve wider and more effective opportunities to engage the public. Our country's future depends on the abilities of the public to plan proactively for the complexities of the 21st century. We believe effective storytelling combined with the successful implementation of sophisticated, networked visualization tools inspired by the Fuller's Geoscope are key components needed to address the climate literacy problem at all levels of society.

This insight is particularly relevant within the context of the International Society for Digital Earth. The vision of a climate literate society will require the physical scientists, social scientists, educators and technical experts to work in unison, synergizing our capabilities to fulfill Fuller's vision of the digital earth. As Helga Nowotny so eloquently wrote: "Innovation is the collective bet on a common fragile future, and neither science nor society knows the secret of how to cope with its inherent uncertainties. It can only be accomplished through an alliance among the participants and a shared sense of direction" (Nowotny, 2005).

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