Communicating atmospheric science and research to diverse audiences using a field campaign

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ABSTRACT

There are growing concerns among the nation’s leading science organizations about the American public’s lack of scientific literacy, participation in science, and understanding of the value of scientific research. Coupled with these concerns is the need to improve the communication of science and research to our diverse populations, and to include them in the scientific process. As these concerns extend to atmospheric processes, the effects could be magnified: the atmosphere dynamically changes from calm weather conditions to extreme high impact events that significantly affect community services and decision-making processes. However, efforts are under way to address these concerns by bridging the gap between science and community service. In recent years, research field campaigns have emerged as effective tools for communicating science and engaging science participation. They help to facilitate the understanding of atmospheric processes by the public, and their collected data sets are potentially useful for formal and informal science education and communication. Through funding from the National Science Foundation, campaigns such as T-PARC are being used to develop instructional materials to improve the public’s scientific knowledge, foster science literacy and participation, and to prepare the next generation of scientists from diverse backgrounds. In the present study, instructional materials have been presented in a variety of media with the goal of including these diverse audiences in the scientific conversation.
I. Introduction

Communicating science and research are critically important steps toward improving scientific literacy and participation in the United States, and for establishing mutual confidence between the public and scientific communities (Todesco et al., 2006). It is essential for advancing community engagement in public and scientific discourses. For many natural phenomena involving the weather, it is integral to decision-making processes, public weather perceptions, understanding of climatic conditions, and to capital investments in research. The United States government has given this priority with the “enhancement of environmental literacy and improvement of the understanding, value, and use of weather information and services” (NOAA, 2005). The American public in turn is genuinely interested in scientific discoveries emanating from research laboratories because their products significantly influence personal decisions and those of policy makers (Hart, 2002 and Priest, 2001). Atmospheric research represents the ideal tool for communicating scientific information due to not only the risks from weather systems, but as the atmosphere is a dynamical system, it can be used as an instrument to foster participation in scientific inquiries. It is moreover an important and popular topic of discussion among scientists, the public, students, teachers and others capable of engaging learning and enhancing science literacy efforts.

Expanding the dialogue of atmospheric research requires scientific communities to increase the number of participants involved in the exchange of scientific knowledge. Diverse audiences (individuals and groups from various cultural, socioeconomic or ideologicstic backgrounds) must be included in the processes used to acquire scientific data, and the dissemination of such information. This is particularly true for many natural phenomena as science communication
represents the first steps toward becoming aware of the complex processes characteristic of these phenomena. Researchers must demonstrate the progress, or lack thereof, made in advancing their research goals, as well as the benefits that the public may gain from investing capital into research. Capital here represents temporal, monetary, cultural and societal assets. Scientific investigations, and their processes, must therefore utilize physical and social theories and learning best practices to achieve their objectives. These investigations must also move towards an agenda for advancing research beyond the traditional media for communicating their results (Rennie et al., 2003).

Communicating the advances and the limitations of atmospheric research are particularly important for increasing understanding of the environmental conditions distinctive of our atmosphere. According to Gigerenzer et al. (2005), public audiences are inadequately knowledgeable of weather messages and terminologies essential for responding to these characteristic conditions. Powell et al. (2007) maintained that if these audiences failed to understand common meteorological messages, they would probably fail to adequately grasp other important terminologies. In terms of the stunning global statistics of weather disasters, this catalytic effect can be significantly magnified. Weather disasters represent a significant percentage of the global statistics of natural disasters: ~75% of the incidence of disasters, ~66% of the property damage, ~90% of the number of people impacted and ~98% of fatalities\(^1\) (Powell et al., 2007). Accordingly, weather-related discourses should be audience appropriate, comprehensible, relevant and/or useful, systematically presented, and address important societal

\(^1\) See for example the OFDA/CRED international disaster statistics at [http://www.cred.be](http://www.cred.be)
problems. In this paper, we sought to address this communication need and stop the cycle identified by Powell.

THORPEX (The Observing System Research and Predictability Experiment), a research and development program established by WMO/WWRP\textsuperscript{2} is the medium through which we communicate the science and research of the atmosphere. Specifically, we used the sub-program Pacific-Asian Regional Campaign (T-PARC), and its data, to develop innovative products to incorporate diverse audiences into science and research. Scientifically, the T-PARC field campaign sought to reduce the short-range dynamics and forecast problems (large forecast errors) in the western North Pacific and the resulting medium range dynamics and forecast problems experienced over the eastern North Pacific, North America and the North Atlantic (Parsons \textit{et al.}, 2008). Forecasting, and correcting for these errors, has been increasing over the decades at one day of progress for every ten to fifteen years. However, these increases in forecast skills are being outpaced by great demand for accurate weather information with reduced forecast errors, and widened gaps between weather forecasts and societal benefits. Gaps in forecast applicability and societal benefits were infamously demonstrated during the 2005 Hurricane Katrina and 2003 European heat wave events (Morss \textit{et al.}, 2008). These examples highlighted the immediate need for the T-PARC program to address the burdens placed on weather forecast systems and to be an instrument to communicate the societal gains from improved weather predictions and research.

The authors here hypothesized that through research field campaigns, such as T-PARC, improved understanding of atmospheric science and research could be achieved. Similarly, we

\textsuperscript{2} World Weather Research Program of the World Meteorological Organization
could advance the transfer of science using such campaigns. It was therefore proposed to accomplish these goals through the production of learning materials that would incorporate diverse audiences into the science conversation of the atmosphere.

II. Methods

The T-PARC data and field campaign were the vehicles through which the science of the atmosphere and atmospheric research were communicated. These T-PARC products were used to develop three documents for three distinct media to reach the greatest number of people. The media and documents included a popular literature science article, an atmospheric science homework assignment, and a museum exhibit. Each document was developed to meet the science communication and learning needs of adult learners, students and teachers, scientists and the general public.

The three documents were developed using guiding best practices from formal and informal education. Other best practices and recommendations from publications in the field were referenced (Knowles et al., 1998; Arndt et al., 2008; Rennie et al., 2003). Each product was developed using the “andragogical model” (Knowles et al., 1998; Arndt et al., 2008), which presented six major assumptions about adult learners that the authors of this paper believed would support learning and information transfer irrespective of age. The six assumptions included the need for adult learners to know, learner’s self-concept, the role of experience, readiness to learn, orientation to learning, and motivation. These assumptions followed that learning from atmospheric science and research discourses could be achieved where the discourses were audience appropriate, comprehensible, relevant and/or useful, systematically
presented, and address important societal problems. The implications of these assumptions are discussed in detail in Section IV.

Brief surveys from museum visitors, former teachers, exhibit designers, and scientists were conducted to determine important practices and recommendations essential for guiding the documents development. The respondents included science center visitors, former teachers, T-PARC field project managers and scientists at the National Center for Atmospheric Research. Each individual was asked key questions about learning from their experiences, communicating science and research, and effective instructional designs that facilitated learning and/or science communication. The surveys were presented in Appendix 1.

The methodology proposed by McInerney et al. (2004) was used for selecting the appropriate popular literature for publishing the science article. McInerney et al. (2004) defined popular literature as stories that appeared in newspapers, magazines, on Internet Web sites and/or on broadcast media. Controlled vocabulary, field searching, and advance command language were used to assess the content and audience appropriateness of the popular literature. The popular literature chosen was refined to one based on criteria reported essential for communicating science by respondents of our survey.

The homework assignment was produced for students studying atmospheric dynamics and chemistry, weather forecasting and/or thermodynamic charting. The assignment was developed using a project-based approach to learning and teaching to accompany thermodynamic and forecasting lectures. Project-based learning is designed to empower students to acquire scientific
knowledge and professional skills through active engagement in inquiry activities. Students used atmospheric sounding measurements from the T-PARC’s vast dataset, and the attached instructions (see Figure 1), to construct a thermodynamic chart, a skewT-logP diagram, and predict the atmospheric conditions during the field campaign. An answer key was developed in addition to the assignment to aid instructors grade students’ responses and progress. The key also served to assess student understanding, and guided important concept development.

The final document, the museum exhibit, was designed using instructional design concepts of informal education. The exhibit provided a visual representation of the T-PARC field campaign where, using discovery learning, new knowledge is created within and around the exhibit. Interested learners gained knowledge from the processes used to collect scientific data during the campaign, the instrumentation, and the high-impact atmospheric phenomena that were investigated.

Each campaign document was assessed so that it adhered to the best practices stated above. Science educators and writers, and scientists affiliated with NCAR and/or the T-PARC campaign reviewed the science article. Teachers were chosen to assess the homework assignment, the appropriateness of the instructions and its relevance to thermodynamic or atmospheric science lectures. Visitors to the NCAR Mesa Laboratory Visitor Center, scientists and exhibit designers evaluated the museum exhibit. These reviews and feedbacks were used to guide the development process, and they served as quality control measures.
III. Results

The three products developed from data obtained during the T-PARC field campaign, and the campaign catalog, are presented below. Figure 1 showed a display of the homework assignment. It contained instructions and learning objectives for constructing the thermodynamic chart and predicting the atmospheric conditions during the field campaign. In addition, there are sections providing an overview of the T-PARC, detailed questions to develop student understanding of thermodynamic charts and weather prediction, and resources for both students and instructors.

Figure 1 shows the homework assignment design for an atmospheric science class to aid lecture instructions on dynamics and chemistry, weather forecasting and thermodynamic charting.
Figure 2 showed the homework activity key designed to assist instructors grading the assignment. The key provided answers for the questions and definitions to the important concepts and terms. The key extended to give an interpretation of the skewT diagram.

Figure 2. The answer key for the homework assignment.

Figure 3 showed the science article presented in a published format for the popular literature called Popular Science Magazine. The science article provided an exploratory account about learning from research field campaigns such as the T-PARC. The article explored how these campaigns are viable and important tools for communicating science, and including diverse audiences into science conversations. It used the monumental
Perfect Storm\(^3\) (combination of a strong extratropical cyclone and Hurricane Grace), named by the National Weather Service, as the reference point for relating scientific discovery to the societal need/service for research, and improving scientific literacy and participation.

The final campaign product, an exhibit, is represented in Figure 4. As an interpretative examination of the T-PARC field campaign, the exhibit showed an illustrative design used for learning about atmospheric science and research. Designed for a general audience of museum visitors and other interested groups, the exhibit offered a visual representation of the T-PARC’s instrumentation, scientific and experimental goals, and educational application.

Figure 4. This figure shows the developing exhibit that illustrates the T-PARC field project. The figure provides an interpretative examination of the field campaign and presents a visual representation of the instrumentation, scientific and experimental goals, and educational application for the campaign and its data. The figure to the left shows the exhibit sketch and the figure to the right shows the second stage development.

IV. Discussion

\(^3\) [http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/cyclones/pfctstorm91/pfctstorm.html](http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/cyclones/pfctstorm91/pfctstorm.html)
The production of the three campaign products sought to integrate successfully the best practices in formal and informal education. Similarly, the selected media that followed from these products attempted to utilize these practices to meet the learning goals, and needs, of a diverse audience of learners. As Hart (2002) and Priest (2001) contended, the American public is genuinely interested in science, scientific discovery and the results from experimental research. As this relates to the atmospheric sciences and research, the authors are presented with a unique opportunity and test to provide these audiences with an equally unique community service, *i.e.*, communicating scientific research through distinct medium.

Research field campaigns and the data that they collect are opportune tools that can incorporate large and diverse audiences into science and research. With our dynamic atmosphere as vehicle through which campaigns such T-PARC are conducted, there are multiple avenues through which groups of students, teachers, scientists, policy makers and the general public can participate. In this paper, we looked at three avenues or media: popular literatures, classrooms and museums. Each used data collected from T-PARC, and the campaign’s NSF-supported scientific and experimental objectives, to present the three documents that would communicate the science and research of the atmosphere to these different groups. The diversity of these media and subsequently the products offered what Falk, Martin, & Balling (1978) saw as novel environments that can stimulate curiosity in science lessons. Creating the three documents that integrated formal and informal education offered flexibility and reduced rigidity, while providing a formal structure familiar to many. This gave learners room to learn about the atmospheric sciences and field observations as they attended to what interested them.
The best practices used in the development of three campaign documents employed learning concepts that would facilitate retention and proactive engagement in atmospheric science and research. These learning concepts included interactivity through performance, relevance and/or useful, feedbacks and assessment. The documents were designed and tailored for specific audiences through simplicity, appropriateness, comprehensibility, relevance or usefulness, and clarity. These are particularly important practices for learning about the science of the atmosphere. As the Gigerenzer et al. (2005) survey of New Yorkers identified, lack of grasp of weather information can lead to misinterpretation of probabilistic forecasts common in daily weather reports. Misinterpretations can systematically result in unwarranted anxiety and lack of preparedness for high-impact weather events (Powell et al., 2007), the events that the T-PARC sought to address through improved forecasting capabilities. For individuals lacking prior knowledge of these atmospheric processes, the simplicity and comprehensibility of the documents facilitated learning across media.

Learning is an ongoing process and communicating science and research is critically important to enhancing scientific literacy and participation efforts. Through varying contact points such as classrooms, museums or online websites, diverse audiences can be included into the scientific process. As the “andragogical model” (Knowles et al., 1998; Arndt et al., 2008) purported, learners can be engaged, irrespective of age. The campaign documents acknowledged the importance of learners to know about the weather and climate, their motivations for knowing particularly as the atmosphere could dynamically affect communities, and the role of experience in understanding scientific information and discourses.
There are key limitations to this project that the authors recognized. The designers of the documents acknowledged this and incorporated the Clark et al. (2008) position that projects should consider detailed job and task analysis as a prerequisite in their instructional models. To avoid the risk of presenting knowledge, instructions, and techniques out of context, we modeled the documents based on a prior publication of one of this paper’s authors. Clarke et al. (2009) purported instructional materials should facilitate near transfer of information across skill levels. Near transfer is a procedural learning goal intended to teach systematic tasks that can be performed similarly each time. This meant that individuals who lack the specific knowledge of the atmospheric processes could learn from the documents because they were designed and produced for a diverse group of inclusive learners.

A fundamental limitation of this project was assessing the documents produced for the selected media. Although the homework assignment was designed with internal evaluation, limited external assessments were conducted on the three documents. This is a concern for us the authors, but this aspect of the project will be addressed after first publication. Feedbacks and other evaluations for all three documents would provide the required assessments for optimal use, and for subsequently campaign products updates. Reviews were slowly returning to us, and were not included here. After addressing the reviews, the documents would be edited, and distributed to the selected media, as well as made available at NCAR.

V. Summary
As scientists, educators, leading science institutions, and others strive to improve the American public’s lack of scientific literacy, participation in science, and understanding of the value of scientific research, research field campaigns have emerged as effective tools to accomplish these goals. Field campaigns such as the NSF-sponsored T-PARC offered all people the opportunity to participate in scientific observations and engaged them through a vast array of resources. The T-PARC, and similar field campaigns, provided unparalleled access to satellite, ground, upper and lower atmospheric, modeling, and experimental data to accomplish defined scientific goals. They also served as invaluable sources for learning and communicating science. Through collaborative efforts, there could be successful dissemination of the scientific knowledge obtained from these campaigns, and an avenue to prepare a scientifically literate population and the next generation of scientists, educators and policy makers.

Expanding the dialogue of scientific research required similar expansion of the media and products used to elicit engagement. Falk, Martin, & Balling (1978) saw this as a crucial step that offered novel environments that stimulated curiosity in science lessons. In the study, the three media and products sought to stimulate such curiosity by creating instructional materials that facilitated learning across media. Where one specific audience may lack the prerequisite knowledge of the atmospheric processes, the audience may gain a summative understanding of those processes through interaction with the other products. Each was designed with the intended purpose to communicate to as many persons the learning opportunities available to them from field campaigns such the T-PARC. This gave learners room to learn about the atmospheric sciences and field observations as they attended to what interested them.
Advancing science and research communication required going beyond the traditional means and media of communication, as well as exploring novel learning best practices. Surveys conducted for this project indicated that the three documents should be appropriately, comprehensibly, relevant and/or useful, and clearly and simply presented to their selected audiences. These were important practices that the authors believed would support learning from the T-PARC, across such media and irrespective of age. Coupled with the “andragogical” model’s six major assumptions about adult learners, these practices used the T-PARC’s data and field expedition to facilitate learning through flexibility and a formal structure familiar to learners.

As we proceed to the next phase of the project, the campaign documents will be assessed so that they adhered to the best practices supported by survey respondents. Comments, feedbacks and other reviews have been slow, minimal at best, returning to the authors. This next phase will produce a separate report for publication on these assessments, as well as updated documents.

VI. References:


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