



# **Data Visualizations:**

## **Year 1 Formative Evaluation**

### *Sea Surface Temperature and Net Primary Productivity*

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**American Museum of Natural History**

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Understanding, fostering, and promoting lifelong learning

**About the Institute for Learning Innovation:**

Established in 1986 as an independent non-governmental not-for-profit learning research and development organization, the Institute for Learning Innovation is dedicated to changing the world of education and learning by understanding, facilitating, advocating and communicating about free-choice learning across the life span. The Institute provides leadership in this area by collaborating with a variety of free-choice learning institutions such as museums, other cultural institutions, public television stations, libraries, community-based organizations such as scouts and the YWCA, scientific societies and humanities councils, as well as schools and universities. These collaborations strive to advance understanding, facilitate and improve the learning potential of these organizations by incorporating free-choice learning principles in their work.

## Executive Summary

The American Museum of Natural History (AMNH) received a NOAA-ELG grant for a three-year project, entitled *Exploring Earth Systems: Expanding Data Visualizations Experiences for Museum Learners* (or Data Visualizations). The project focuses on the development, testing, and distribution of Visualizations for the Earth and Bio content strands of the AMNH's Science Bulletins program. The Visualizations are short media pieces that use satellite data to tell the story of Earth processes on land, in the oceans, and in the atmosphere, with the larger goals of helping viewers to understand the dynamic and changing nature of Earth's systems.

The Institute for Learning Innovation is serving as the independent, external evaluator for the three year life of Data Visualizations. This report documents the findings from the Year 1 formative study conducted in January 2011, which focused on the Visualizations entitled *Sea Surface Temperatures* and *Net Primary Productivity*. These existing Visualizations were candidates for new treatments under the grant; the results of the formative evaluation will aid the AMNH team in designing updated Visualization on these same topics. The results also have implications for the AMNH team as they develop other Visualizations over the course of the project since and future Visualizations will have many elements in common with the pieces developed in Year 1. The formative study gathered data from visitors to the AMNH using focus groups; visitors viewed the two Visualizations and provided feedback on the strategies used to display the data as well as the content. The results are organized around two primary evaluation questions:

### **How effective are the strategies used in the visualizations at conveying basic information to visitors?**

Viewers, overall, were able to make sense of the Visualizations at the most basic level. Participants in the focus groups were able to interpret what was being displayed, and there were very few differences in how adults and children understood the Visualizations.

A common theme throughout all groups was the multiple areas of the Visualizations that compete for the viewers' attention. Competing elements included the captions, the date, the color legends, and the eye-catching and dynamic nature of the data being displayed.

Most groups had some difficulty with the pacing of the Visualizations. This was closely linked to the amount of information being displayed, with pacing becoming problematic when viewers felt multiple areas of the Visualization were competing for their attention. The complexity of the topic and participants' incoming familiarity with the topic also may impact visitors' perceptions of the pace of the Visualization.

The team could consider the following changes to improve "readability" of the Visualizations:

- Allow time at the beginning of the Visualization for viewers to orient themselves to the data being displayed before beginning the captions.
- Label the continents and oceans, especially when using atypical views of the globe.
- Include a line for the Equator rather than labeling the Tropics of Cancer and Capricorn.
- Increase the contrast of colors used in *Net Primary Productivity* and reconsider the use of grey for areas of no data.

- Interpretation of areas of no data may be needed in *Net Primary Productivity* since it was a common question raised by viewers.
- Use a horizontal bar for the color legends.
- Create additional opportunities for comparing two points in time using multiple globes.
- Move all captions to the bottom of the screen.
- Use real images of conditions “on the ground.” A technique like the picture-in-picture used in *Science on a Sphere* may be appropriate. Another option is to use a satellite image, like the one in *Global Fires 2002-2008* where smoke from fires in October 2007 is visible from the air.

### How effective is each visualization in conveying its “big idea”?

Participants overall were able to make meaning from the Visualizations and understood the main topics of the Visualizations. While participants had the prior knowledge needed to make sense of these Visualizations, this may not be true for other topics under consideration.

The findings from the study indicate that topic choice and conveying the implications of the topic to the viewer are very important. Viewers found *Sea Surface Temperatures* to be more compelling overall than *Net Primary Productivity*; this finding may be a result of the main messages of the Visualizations and the lack of new information in *Net Primary Productivity*.

When responding to the Visualizations, some participants made comments that revealed they were misinterpreting or reading more into the data than was really there; they may have been using their existing knowledge of global warming to draw conclusions that were not presented in the Visualizations. Participants may have been interpreting naturally occurring seasonal or annual fluctuations as evidence of global warming.

The team could consider the following changes to improve the effectiveness of the Visualizations at conveying the main message and achieving the goals of the project:

- Choose topics that have compelling implications or answer the question “so what”.
- Consider making connections to global warming and climate change more obvious.

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## Introduction

The American Museum of Natural History (AMNH) received funding through the NOAA Environmental Literacy Grants (ELG) program to “create and disseminate widely a suite of visually rich media productions that will engage, educate, and inspire public audiences about dynamic Earth systems.”<sup>1</sup> The three-year project, entitled *Exploring Earth Systems: Expanding Data Visualizations Experiences for Museum Learners* (or Data Visualizations), is one of a suite of projects within the AMNH’s Science Bulletins program. Science Bulletins are video content and interactive media for use in a variety of settings, including on the museum floor and online, and are distributed to a network of ISE institutions. There are four content strands within the Science Bulletins program (Astro, Earth, Bio, and Human) and a variety of presentation types (Features, Snapshots, Visualizations, and Events). The NOAA-ELG grant-supported project is designed to support the development, testing, and distribution of Visualizations for the Earth and Bio content strands.

Within Earth and Bio Bulletins, Visualizations are short media pieces (between 2.5 and 3 minutes in length) that use satellite data to tell the story of processes on the Earth’s surface. Satellite data is displayed using a “birds-eye” view of the whole earth or particular regions. Earth Visualizations focus on atmosphere, climate, and weather; Bio Visualizations focus on ecosystems and human impacts (such as urban sprawl). Strategies used to display the data and support its interpretation include the color enhancement of the data, keys and legends, indications of the time period over which the data were collected, labels to indicate features of the data or geography, and captions which convey the story of each Visualization.

Although each Earth and Bio Visualization created for the project will focus on a separate topic and have its own sub-set of learning outcomes, overarching learning outcomes guide all Visualizations created for the project. As a result of viewing a Visualization created for the project, visitors will understand that:

- Earth systems are dynamic.
- There are natural seasonal variations, annual fluctuations, and long-term patterns within Earth systems.
- There are longer-term changes to Earth systems that can be tied to human activity.
- There are differences between variations in Earth systems that are natural versus those changes that are “forced” by human activity.
- Scientists use satellites to collect global data that provide evidence of changes in Earth systems.
- Data collected by scientists can be used to document what has happened and to project what will happen within the changing Earth systems.

The Institute for Learning Innovation (ILI), a not-for-profit research and evaluation organization focused on learning in free-choice/informal contexts, is serving as the independent, external evaluator for the three year life of Data Visualizations. In Years 1 and 2, ILI researchers are conducting formative evaluation; Year 3 will focus on summative evaluation. This report documents the findings from the Year 1 formative study conducted in January 2011, which focused on the Visualizations entitled *Sea Surface Temperatures* and *Net Primary Productivity*.

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<sup>1</sup> From the grant proposal narrative.

## Background on the Selected Visualizations

In the grant proposal, AMNH staff identified a set of topics to be developed into Visualizations over the course of the project. Included in the set of topics were ones for which the staff had previously created Visualizations. These existing Visualizations were candidates for new treatments due to the time that had passed since their creation and because of the storytelling opportunities they presented. The AMNH staff decided that their initial Year 1 efforts would focus on creating new Visualizations for two topics with existing versions: *Sea Surface Temperatures (SST)* and *Net Primary Productivity (NPP)*. Before undertaking the creating of the new versions, it was decided to screen the existing versions with AMNH visitors for their feedback. The study that emerged is, therefore, formative within the context of the current project, but remedial evaluation for these two Visualizations. The following descriptions of the content of each Visualization are posted on the Science Bulletins website (<http://www.amnh.org/sciencebulletins/>):

*Sea Surface Temperatures* (Posted April 2006): Long-term observation of sea-surface temperatures reveals patterns and cycles of variation caused by seasonal winds, Earth's rotation, and other factors. This video shows sea-surface temperature measurements across the globe obtained by the Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite instruments. The historical data, gathered by AVHRR from 1985 to 2002, are shown in measurements of degrees Celsius. The current MODIS data (2002-2006), also in degrees Celsius, show deviations from long-term averages. Satellites provide scientists with a picture of what's happening daily over the entire Earth. The United States satellite measurement program for sea-surface temperature, run by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), has gathered global measurements daily since 1979.

*Net Primary Productivity* (Posted October 2006): Scientists use satellite observations to analyze plant growth rate on land and in the ocean. Outside the tropics, plants grow faster as Earth's tilt makes light available in spring and summer. In the tropics, some regions don't have enough water to support year-round plant growth, despite an abundance of light. Light changes with the seasons, and the biosphere responds.

## Evaluation Questions

The results from this study will be applied directly to the newly created versions of SST and NPP, but also have implications for the AMNH team as they develop other Visualizations over the course of the project. The following questions were developed to guide the Year 1 formative evaluation:

1. How effective are the strategies<sup>2</sup> used in the visualizations at conveying basic information to visitors?

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<sup>2</sup> The strategies used the Visualizations include the color enhancement of the data, keys and legends, indications of the time period over which the data were collected, labels to indicate features of the data or geography, and captions which convey the story of each Visualization. How these strategies are implemented vary from Visualization to Visualization.

- a. Are visitors able to make sense of their placement geographically, spatially, temporally?
  - b. In what ways does the visualization help visitors make sense of their placement geographically, spatially, temporally?
  - c. How do techniques like color variations and scales, time scales, and other “orienting” devices support or hinder visitor understanding of the visualization?
  - d. What additional support do visitors need to understand the visualization at its most basic level?
2. How effective is each visualizations in conveying its “big idea”?
    - a. Are visitors able to make meaningful interpretations of what they are seeing?
    - b. What is the role of prior experience—with visualizations or with the topic—in visitors’ ability to make sense of what they are seeing?
    - c. What additional support do visitors need to understand the visualization at a level that achieves the project’s learning objectives and the visualization’s learning outcomes?

## Methods

On January 22 and 23, 2011, ILI staff undertook 6, 1-hour focus group discussions with visitors to AMNH to gather feedback on the existing Visualizations *Sea Surface Temperatures* (SST) and *Net Primary Productivity* (NPP). Groups were recruited near the main entry of the museum by a team of two researchers. Visitors were invited to attend with their entire visiting group, with the majority of visiting groups consisting of two to four people. Due to the team’s interest in the views of youth in middle and high school, at least one family group with children in this age range was recruited for each focus group; youth were accompanied by their parents at all times. In exchange for their time, each visitor was given a SuperVoucher pass for free admission to the museum and all paid programs and \$50 in cash per family/visiting group. Before the focus group began, adult members of the focus group read and signed a consent form disclosing the purpose of the study, the incentive, and the audio recording of the discussion.

The discussion (see Focus Group Protocol, Appendix A) began with an orientation to a focus group and discussion about top-of-mind ideas concerning earth and science climate. The majority of the discussion time was focused on viewing and providing feedback on the two Visualizations. Each Visualization was played through once in its entirety, followed by a short conversation about main messages of the video and initial feedback. Then the Visualization was shown a second time allowing for a guided deconstruction of the piece with participants giving feedback. The same procedure (two viewings, the second one guided) was used for the second Visualization.<sup>3</sup> Finally, participants were asked if they felt any differently about the Earth as a result of viewing the Visualizations. Each focus group was audio recorded. One member of the research team facilitated the conversation while the other took detailed notes during the conversation. The notes and recordings served as the basis of analysis. Analysis consisted of inductive and deductive coding techniques to identify trends and themes in the data.

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<sup>3</sup> On January 22, NPP was shown to visitors first, followed by SST; on January 23, the order was reversed. This approach was used to account for viewers’ growing familiarity with the style of the Visualizations; researchers wanted to be able to control for the potential that participants’ reaction to the second video were more favorable because they were now familiar with the presentation style. In actuality, the order of the videos did not seem to impact participants’ responses.



## Findings

An overview of the study participants and the findings are presented below, with findings organized by the major evaluation questions for the study. While the original intent of the study was not to compare SST and NPP, many of the focus groups naturally made comparisons between the two Visualizations. As a result, some of the findings are presented as comparisons between the two Visualizations where this technique serves to illuminate participants' reactions.

### Participants

The focus groups participants were diverse consisting of adults and youth, groups living in the US (Florida, New York, New Jersey, and Washington DC) and international visitors from Brazil, Mexico, Germany, and Ireland. English was not the first language for three of the families/visiting groups. A few of the adults were continuing their education, but the majority were working, with careers including emergency medical technician, doctor, chef, farmer, jewelry sales and design, yoga instructor, university professor, and graphic designer. The following list details the make-up of each group:

- Group One: Family group of four, including an 8<sup>th</sup> grade girl and 7<sup>th</sup> grade boy; a couple in their twenties.
- Group Two: An extended family group of two adult women, two adult men, one 4<sup>th</sup> grade boy, and two girls in 6<sup>th</sup> and 10<sup>th</sup> grade.
- Group Three: Family group of four, including a 9<sup>th</sup> grade girl and 6<sup>th</sup> grade boy; a couple in their twenties.
- Group Four: Family group of three, including two teenage boys; a family group of four, including a boy in middle school and a 9<sup>th</sup> grade girl.
- Group Five: Family group of three, including a 12 year old boy; Two men in their late twenties or early thirties.
- Group Six: Family group of three, including an 8<sup>th</sup> grade boy; Two women and one man in their early thirties.

Participants seemed primed to learn the type of information that aligns with the goals of the Data Visualizations project. When asked what came to mind when they heard the words “earth and climate science,” the most common response was “global warming.” Participants mentioned the impacts of global warming on the environment, humans, and animals. Typical comments included the following:

*The ice caps turning into a pool, ozone and cancer. (Adult Female, Group 1)*

*I think about penguins not having a place to live and certain animals dying off—becoming extinct in a very short period of time. (Adult Female, Group 1)*

*Drastic changes all around the world. We are from India, and it never used to be cold, especially around Mumbai...but this year it was really cold...And for New Jersey compared to last year, there is more snow and more snow. (Adult Female, Group 2)*

A few visitors talked about the politics involved with climate science:

*If you get on CNN even once a week you are going to hear something going on. Either some sort of funding or money issue with it, or some scientific breakthrough, or the two arguments. Some scientists saying it's not a big thing and some are saying it is a big thing. (Adult Male, Group 1)*

*You have these opposing view points and a lot of it is politically driven. How do you agree that your money is supposed to go there? So it's very difficult. (Adult Female, Group 6)*

When discussing the phenomenon, none of the participants seemed skeptical about the existence of global warming. Most participants said that they had gotten this information from the media, including shows on the Discovery Channel and National Geographic, the news, or from reading about it. Participants who were in middle or high school said that global warming is an issue they hear about in class as well as from the media.

### **How effective are the strategies used in the visualizations at conveying basic information to visitors?**

This evaluation question looked specifically at the design elements or strategies used in the Visualizations to display the data and how well these strategies conveyed information. The strategies used in these Visualizations include the color enhancement of the data, keys and legends, indications of the time period over which the data were collected, labels to indicate features of the data or geography, and caption placement and speed. In this section, general participant feedback is presented first, followed by feedback related to specific strategies.

Participants, overall, were able to make sense of the Visualizations at the most basic level; they were able to interpret what was being displayed. This was despite their limited experience with images of this type. Very few participants reported having seen similar visualizations before. Of those who had, they said they had seen similar videos in school or on National Geographic; none mentioned other NOAA data visualization projects such as Science on a Sphere.

A common theme throughout all groups was the multiple areas of the Visualizations that compete for the viewers' attention. Competing elements included the captions, the date, the color legends, and the eye-catching and dynamic nature of the data being displayed. For many, the result was they did not know where or what to focus on. "I didn't know where to concentrate on. It was making me working too hard, I felt like I would have to watch it three times," responded one man. Some expressed a desire to just watch the data being displayed before having to read and interpret the other elements. Others wondered if the amount of information could be limited somehow (such as displaying only the years and not the months) or if the viewer's attention could be focused on the relevant element with a cursor or circle. A high-school age girl said, "They have details but they just have to make them more noticeable without the audience getting distracted and taking away from the bigger picture."

Also problematic for most groups was the pacing of the Visualizations. For many viewers, pacing was closely linked to the amount of information being displayed, as in the following conversation from group 3:

*Youth Female: It's fast! You are trying to read the words, look at the key down there, then you are trying to look at the picture.*

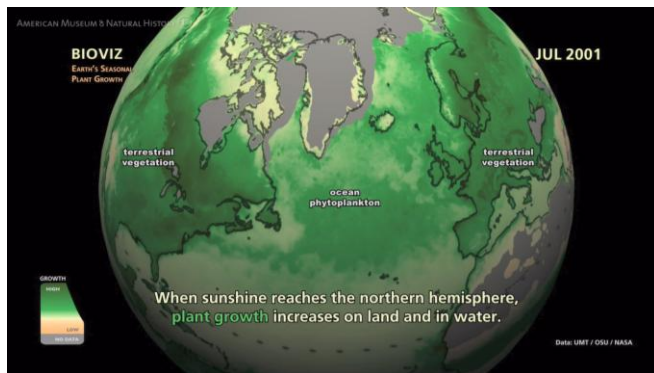
*Adult Female: It was very informative but it was too fast and then there were some other distractions.*

Participants were more likely to comment that SST was moving too fast, where as the pace of NPP was more comfortable. However, this distinction likely was impacted by the complexity of the information in SST compared to NPP. It may be that the more complex the topic, the more pacing becomes an issue for viewers.

### *Feedback on Specific Strategies*

#### Geographical Location

In general, the vast majority of participants were able to orient themselves geographically when viewing the Visualizations. The exception was a few middle-school aged children who were at times confused and unable to accurately identify continents or oceans. Particularly difficult for this age group were atypical views of the globe, including unusual angles or where whole continents are not visible. These techniques were used more often in NPP than SST, as seen in Image 1. Using the same colors in both the water and the land may have added to the difficulty in identifying geographical location; the expectation is that water and land will be represented in contrasting colors. In fact, two groups suggested using a different color for the oceanic plant life to help differentiate the oceans from continents.

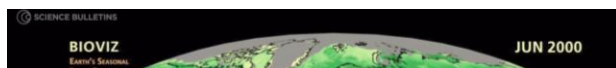


Participants drew on their existing knowledge of geography in order to identify the majority of features in the Visualizations as the labeling was very minimal. What labeling there was (of the Tropics of Capricorn and Cancer) was not always visible. Some participants suggested including the Equator, suggesting this would be helpful for younger children. Others thought that labeling the oceans and continents would help younger viewers.

*Image 1: View of the North Atlantic, NPP*

#### Temporal Location

Participants had minimal difficulty in interpreting the timestamps used in both Visualizations. In general, participants found the timestamps helpful. At the same time, however, many viewers felt that the timestamp and data were changing too quickly, with the implication being that this competed with the other information being displayed. “One of the things that I thought would have been more helpful is for one of the cycles, for a year, slow it down a little bit,” suggested one man.



*Image 2: Timestamp, NPP*



*Image 3: Timestamp, SST*

The two Visualizations used different techniques to note the month and year of the data being displayed (Images 2 and 3). In NPP, the timestamp is text in the upper right corner of the screen; in SST, the timestamp is a bar at the top of the screen where the month is highlighted and the year is text. Both styles of timestamps had elicited positive and negative feedback. For NPP, a few participants questioned

the need to include the month, saying the year alone would provide enough information without being as distracting. Similarly, some participants suggested that in SST, the months could be grouped in to four groups of three to minimize the distraction of the constant scrolling. Most groups, however, preferred the bar style of timestamp used in SST.

### Color Choice and Legends

Participants had a great deal of feedback about the color choice and legend used in NPP (Image 4). In terms of the range of colors, there was a general consensus that dark green was a good choice for the areas of high plant growth. However, many participants felt there was not enough contrast between the dark green and the light tan used for low plant growth. The suggestion was made by two groups to make the low growth color “darker” or “harsher,” with dark brown proposed as a possibility. As mentioned in the findings on geographical location, some participants suggested using a different color for the ocean plant life versus the terrestrial plant life. This suggestion would likely complicate the “reading” of the data and would require two legends. A more straightforward solution may be to label the continents. The use of grey for areas of “no data” was also problematic for some viewers who found the color “unfriendly.” Others felt the grey drew their attention more than the green, where as it should be the reverse. A more significant problem seemed to be that some viewers were confused by the areas of no data, with some interpreting it to be ice, and others wondering why no data was collected (see the section below entitled “How effective are the visualizations in conveying the ‘big idea’ of the piece?”). In terms of the legend in NPP, participants felt it was too small and that the font size of the labels was also too small. They suggested making the legend larger and using a horizontal bar like in SST.

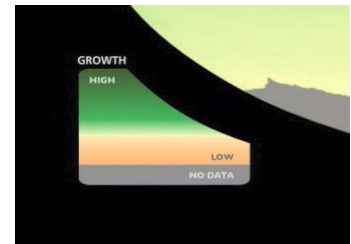


Image 4: Data Legend, NPP

Participants in general made very few spontaneous comments about the color choices and legend in SST. When asked by the researcher, participants indicated that the colors were pleasing and intuitive. A few participants wondered why the temperature was labeled in Celsius rather than Fahrenheit. A topic that was raised in two groups was the shift from displaying the actual temperature to the relative temperature. In one group, this change was seen as too subtle since the same colors (blue and red) anchored both scales (Images 5 and 6). Another group felt that if it was important to understand that the second half of the Visualization was about “relative” and “average” temperature then some device (i.e. a more obvious color change or captions on the importance of relative temperature) should be used to call viewers’ attention to the change from one scale to the other.

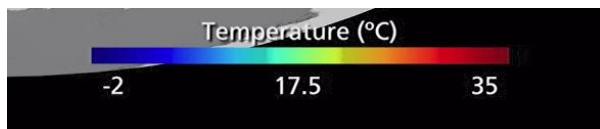


Image 5: Data Legend: Actual Temperature, SST

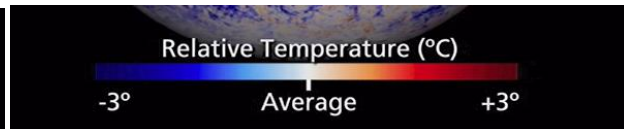


Image 6: Data Legend: Relative Temperature, SST

### Globe Effects

Participants also gave feedback on various visualization techniques including the world view used, the spinning globe, and the use of two globes to compare data. Both Visualizations used two distinct ways to view the Earth, 1) the map view, shown in Image 7, and 2) the globe view, shown in Image 8. Participants in two of the focus groups talked about the pros and cons of these different views. Of particular concern to these participants was the balance between viewing all the data at once and focusing the viewer’s attention. Viewers liked being able to see all the relevant data at the same time

and felt the map view served this purpose. However, they also understood that at times, it was necessary to focus attention on one area of the world. Some felt the globe view was very good at focusing the viewer's attention. Others felt that a "zoom" technique on the map view would serve the same purpose. Specific suggestions on the technique included:

- Using the map view for the scenes in SST where areas of drought and flooding are highlighted.
- Reverting to the map view in NPP sooner perhaps directly after the focus on the southern hemisphere so that the discussion of the tropics occurs on map view.
- Not transitioning from map view to globe view in SST at the same time the transition from actual to relative temperature is occurring.

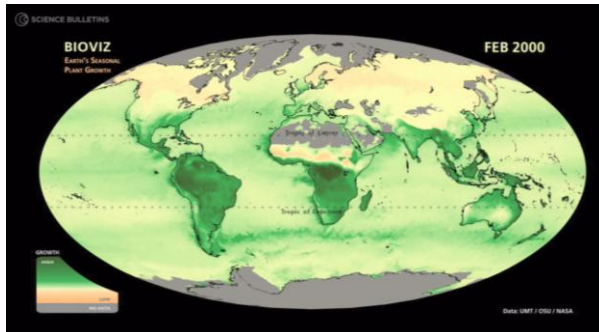


Image 7: Map View, NPP

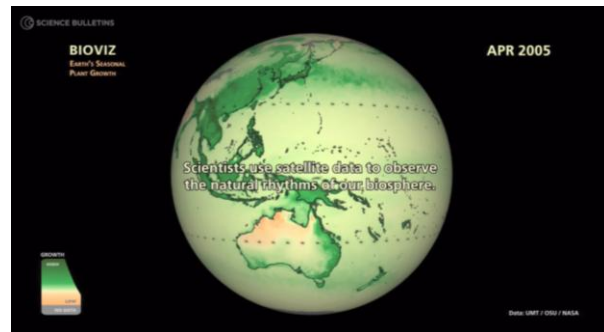


Image 8: Globe View, NPP

A few viewers felt strongly about the "spinning" globe. "The spinning I hate," said one adult woman, "because there is two bits of text you are supposed to be reading [while it is spinning]." The need to spin the globe could be eliminated or limited if the map view was used in situations where relevant data is distributed across the Earth's surface, such as when areas of flooding and drought are highlighted in SST.

A few participants also discussed the comparisons of different points in time or locations using two or more globes, as in Image 9. These participants liked the use of multiple globes in SST to compare a strong and weak La Niña. The suggestion was made to use the technique to compare a strong and weak El Niño and compare El Niño and La Niña to each other. Another suggestion was to compare the Northern and Southern hemispheres in NPP.

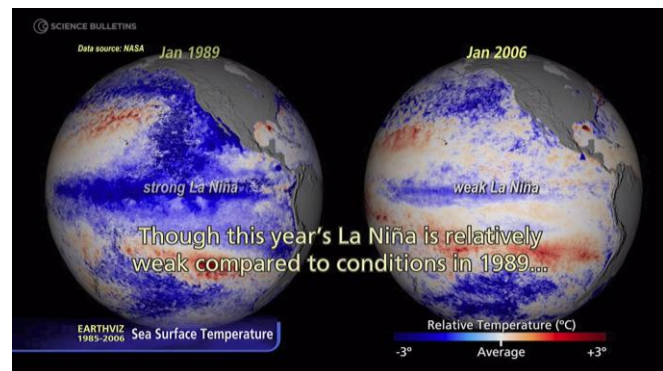


Image 9: Comparison Using Globe View, SST

### Captions, Labeling, and Narration

In general, participants did not feel strongly about the captions or labeling in the Visualizations. Groups typically did not comment on these aspects unless the topics were raised by the researcher. There is some evidence that points towards the need for making the captions more readable or intuitive. A few participants did not like having the words on top of the globe or map, mentioning 1) their existing expectation that captions appear at the bottom of the screen and 2) that the captions would be easier to read at the bottom. A few groups suggested that the captions could go slower, especially those for

whom English was not their first language. One participant visiting from Germany responded that “it was not so good that some was too short to read everything, otherwise I can not understand everything. It was really short to explain everything what they mean...some scenes has to be longer.” Youth did not appear to have any difficulty with the speed of the captions. Participants particularly appreciated using color from the scale to highlight key words. An example of this is in Image 1.

Many participants suggested that narration would be a good addition to the Visualizations. “It looks kind of dull without audio, without explanation of what is going on. So it took a while to understand and also to follow that. A brief audio to explain what is going on...would have been helpful,” commented one man. Narration would reduce the need to read the captions and free up viewers’ attention for other elements of the Visualization that require reading (i.e. the scales and labels). However, as some viewers who were non-native English speakers pointed out, narration could create additional confusion because they some times have trouble with accents.

### Music

Of those who specifically commented on the music, participants preferred the music used in SST to that of NPP. The NPP music was described by one viewer as “repetitive, Clockwork Orange” music.

### Images: The Satellite, Real Images, and the Model of the Earth’s Rotation

Some participants thought the satellite looked like a paint brush or a mop (Image 10). “Is that a broom?” asked one woman, “It looked like a Swiffer or a squeegee.” This impression was supported by the way the satellite seems to “paint” the globe with color at the beginning of both Visualizations.

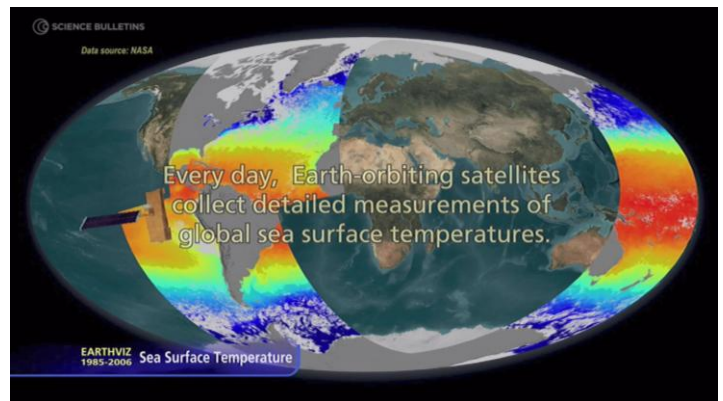


Image 10: Satellite and “Painting Effect”, SST

Some participants suggested using real images in the Visualizations. For example, In SST showing photos of floods and droughts. When asked what he would add to the videos, one teenaged boy replied, “Better images, real images. Like see a place where there is the problems—what it is like right now.”

The model of the Earth’s rotation was commonly noted by participants as a compelling or interesting point in NPP. Although some said it was fairly basic science, it was a topic that multiple families had recently had conversations about in relation to seasonal changes or solar-based holidays. It was also a point in the video where parents and children tended to have side discussions about the image.

### **How effective is each visualizations in conveying its “big idea”?**

Participants overall were able to make meaning from the Visualizations and understood the main topics of the Visualizations. Most participants also indicated that after watching the Visualizations they were more “concerned” about the Earth. Some were struck by the “delicate balance” of Earth’s systems and the overall complexity. The quotations below illustrate these trends:

*It’s constantly changing. (Youth, Group 2)*

*What a delicate balance everything is. You feel kind of small. (Adult Female, Group 1)*

*We think we can control the stuff on this planet, but you realize this thing is a machine. It has its own mechanisms. We can only learn about it and try not to damage it but we can't control it. (Adult Male, Group 1)*

*We have to be more careful about how much liberty we are taking in our day-to-day life. (Adult Female, Group 2)*

The majority of focus groups (5 out of 6) preferred SST to NPP. Researchers felt this preference for SST was likely in response to a combination of factors: 1) the level of information in each Visualization and 2) the perceived lack of a larger “so what” message in NPP. SST as a topic was more likely than NPP to convey new information and as a result was considered less basic. Indeed, visitors were more likely to report that they learned something new when watching SST versus NPP. Participants’ perception of the information combined with a message that was perceived as having weightier implications (“Studying sea surface temperature is essential for predicting weather and understanding global climate”) likely led to a greater satisfaction overall with SSP. This interplay of level of information, topic choice, and the “so what” or implication of the topic is an important consideration for the team in creating Visualizations that are satisfying to viewers. (See the section on NPP below for additional discussion of this topic).

Participants had the prior knowledge needed to make sense of both Visualizations. Many reported having heard about these topics in school or through the media. This result can be interpreted to mean that for *these topics*, the typical AMNH visitor has enough incoming knowledge of the topic to make sense of the Visualizations. However, these topics were relatively basic (NPP in particular) in comparison to other topics that are the subject of current Bio and Earth Visualizations (i.e. *Human Footprint* and *Urban Sprawl: Baltimore*).

Participants identified the primary audience for both Visualizations as being middle and high school students. Many groups mentioned that the films would fit well into science classes for these age groups. There were some differences, however, in the assessment of secondary audiences. Participants were more likely to say that SST was for museum goers. NPP more likely to be described as for late elementary aged children; this supports the idea that this Visualization was too basic for many of the participants.

When responding to both Visualizations, some participants made comments that revealed they were misinterpreting or reading more into the data than was really there. In most of these cases, participants used what they knew about global warming to draw conclusions that were not presented in the Visualizations. As a result, participants had a tendency to interpret what may be naturally occurring seasonal or annual fluctuations as evidence of global warming. For example, the grey area of no data around the poles in NPP was interpreted as shrinking ice caps by a few viewers, with younger participants more likely to reach this conclusion. One adult participant said that the main idea of the SST was “extreme weather and how it’s been increasing or becoming more extreme over this time period.” It may be that participants expected to hear about climate change and global warming, as did one woman who said, “I kept waiting for global warming to sort of surface as a topic because it seemed that as the years progressed more plant growth was happening further north and further south...so I was waiting for the global warming spin but it never happened.” As a result of that expectation, they may have made inferences about what they were seeing.

Participants' understanding of the main messages, areas of new learning, and unanswered questions for both Visualizations are detailed below.

### *Sea Surface Temperatures*

#### Main Message

Participants, in general, understood the main message of SST. Most were able to describe the video accurately with varying levels of detail, ranging from one-word answers to detailed explanations. When asked what they thought the video was about, responses included “the temperature of the seas,” “climate,” “extreme weather,” and “seasonal effects of El Niño.” “[It is] emphasizing the relationship between the sea temperature and the weather systems,” summarized one adult male. A few participants made connections between the data shown and climate change that were not made explicit in the Visualization. For example, one woman in group 2 said, “You could see like how the oceans are getting warmer from like 1985 when we started, and then the warm areas are increasing around the globe.”

#### New Learning

The majority of participants reported learning something new as a result of watching SST. The most common area of new learning was with regards to La Niña; for many participants, watching the video was the first time they had heard of La Niña. This is in contrast to El Niño which most participants indicated they had heard of previously. “I knew about El Niño but I didn’t know about La Niña,” reported one middle school girl. There were no apparent difference between adults and children’s familiarity with La Niña. For participants who did talk about new information they gained relative to El Niño, the most mentioned area of new learning was that El Niño was so common.

#### Unanswered Questions

A few participants in the focus group identified questions they had because the Visualization had not given them enough information or because they were critical of the information presented. Three out of six of the groups had a discussion about the “why” behind El Niño and La Niña. A woman in group 3 said, “The water temperature changes, but it didn’t say why some areas have drought and some areas have flooding. It just said that it happens. There was no explanation.” A boy in group 2 wanted the film to “also show the cause about why it’s colder or hotter.” These individuals wanted to know both the results of these weather patterns and the causes.

Another area where a few visitors expressed concern was relative to the statement “Every 3 to 7 years, surface temperatures along the equatorial pacific become warmer than average.” This statement was seen to be so vague as to be not scientifically accurate: “I think it needs more information...it starts saying every 3 to 7 years it gets warmer, but they didn’t say why. It’s just like we have to buy it,” said one man. At least one group wondered about the differences in El Niño and La Niña due to global warming; they wanted more information on long term patterns.

### *Net Primary Productivity*

#### Main Message

Participants, as a whole, understood the main message of NPP. Most were able to describe the video accurately with varying levels of detail, ranging from one-word answers to detailed explanations. When asked what they thought the video was about, responses included “plant growth due to seasonal



changes,” the role of the sun in plant growth, and differences between the Northern and Southern hemispheres. One man summarized NPP as the “seasonal variations due to the sunlight, the Earth and the axial tilt, and how that effects the seasons and the plant growth.” A few of the participants who were in middle or high school wrongly said the video was about climate change.

### New Learning

Very few participants reported learning anything new from this Visualization. For some of the youngest viewers in late elementary or middle school, the main idea (i.e. seasonal changes in plant growth) was new. A few children and one adult responded that they had not heard the word “phytoplankton” previously, and the term “terrestrial plants” was new for one child. The content, overall, was too straightforward for most viewers. Adults in most of the groups reported learning nothing new, with some saying it was “too basic” and “pretty repetitive.”

### Unanswered Questions

A few participants in the focus group identified questions they had because the Visualization had not given them enough information. Participants in at least three of the groups wondered if low plant growth was due to the lack of water; some said that there was not enough information presented in the Visualization to tell. “Does that also infer that anytime there is a yellow [area] that there is lack of water? I wasn’t clear about that,” said one woman. Participants also wondered about the implication of the areas labeled “no data.” Was there no data in these areas because there were no plants? Or was it not possible to gather data in these regions for some reason? “You’re wondering if it’s a global satellite, how come they have no data?” questioned one man.

### Implications of the Visualization

In about half of the groups, participants voiced opinions about the larger implications, or “so what,” of NPP. This topic came up spontaneously in these groups and was not a question specifically asked by ILI staff. One group commented that the last sentence of NPP (“Scientists use satellite data to observe the natural rhythms of our biosphere”) should have been the first sentence, that the visualization should have started there and gone deeper. Responding to the concluding sentence, one man commented that “If that statement began in the beginning, it would tell me what I was looking at.” Multiple groups felt NPP was too basic, that it needed more detail, as in the following conversation from group 4:

*Adult Female: It doesn’t explain much.*

*Youth Male: It doesn’t talk specifically—it’s something about plant growth, but what is it all about? It needed more details.*

*Adult Male: It’s about nothing. It’s brief information about nothing...*

*Facilitator: Did you think they put too much information in there?*

*Adult Male: No, that is not the problem. The problem is that you are not concluding anything. You didn’t really say a message that you want to say.*

Another group wanted a stronger explanation of “how it is connected to us.” This response could be due in part to the basic nature of the information presented; perhaps participants were looking for the Visualization to introduce new ideas. It could be that participants were anticipating a message that would tie the information presented to some larger themes of climate change or global warming. The proposed treatment for NPP in the grant, however, does reach beyond the current version to make broader connections between the factual science and repercussions in the study of climate. Page 8 of the grant says, “Large-scale shifts in NPP on land and in the water can be seen as signals of global change, including climate change, pollution, and deforestation.” This goes beyond the content of the

current treatment and may prove to be more engaging for viewers; it likely is new information to visitors and tells them the reason for studying plant growth.

## Conclusions and Recommendations

Both Visualizations examined in this formative study were effective at conveying basic information and larger ideas. Participants in the focus groups found the Visualizations to be informative. There seemed to be little difference between the responses of school-aged participants and adults, which indicates that these Visualizations were understandable to the broad age-range of AMNH museum visitors who participated in focus groups. Although many changes were suggested by participants, for the majority of participants the current Visualizations were effective in conveying the intended content.

The findings from the study indicate that topic choice and conveying the implications of the topic to the viewer are very important. Viewers found SST to be more compelling overall than NPP; this result could be tied to the main messages of the Visualizations and the lack of new information in NPP. In comparison to SST's final sentence and main idea ("Studying sea surface temperature is essential for predicting weather and understanding global climate"), NPP's main message ("Scientists use satellite data to observe the natural rhythms of our biosphere") was seen as too basic by participants. Although it was not tested with visitors, it is likely that the treatment for NPP described in the grant proposal would be more compelling and satisfying for viewers.

Visitors to AMNH may have an incoming expectation that the Visualizations will cover topics related to global warming and climate change. The results of the study seemed to indicate that even if such a message is not part of the story arc of the Visualization, viewers may "read" evidence of global warming into what they are seeing.<sup>4</sup> A tendency to look for global warming evidence, while problematic for topics not on this subject, gives the team greater "permission" to cover global warming topics and to be more direct and overt in their treatment. For example, SST could have a much stronger global climate change message such as, "El Niño and La Niña patterns have been getting more extreme in recent decades. Some scientists believe this is a result of global warming" and then present evidence that supports this assertion. It is important for the team to bear in mind that visitors to other museums that receive Science Bulletins may not be as science savvy or accepting of climate change as AMNH visitors.

While the majority of participants in this study had the prior knowledge necessary to understand these topics, this might not hold true for other topics. The team may want to do quick front-end studies with visitors when trying to determine the level of background information visitors have for other topics that are part of the project. Considering that other museums also use the Science Bulletins, it might be valuable to have museums that are unlike AMNH in geographical location and visitorship collect front-end data with their visitors as well.

The pace of videos like the Earth and Bio Visualizations is a delicate balance. Pacing is a combination of multiple factors with viewers attention split between the changing data and reading. The complexity of

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<sup>4</sup> It may also be, however, that the initial focus group conversation about global warming had the participants already thinking about global warming, which led them to expect to that information in the Visualizations. It may also be that many of the media piece on climate science that the participants are typically exposed to have a global warming bent, leading them to expect a global warming focus in the Visualizations.

the topic and participants' incoming familiarity with the topic also may impact visitors' perceptions of the pace of the Visualization. It may be that the more complex the topic, the more pacing becomes an issue for viewers.

### *Recommendations*

The team could consider the following changes to improve the effectiveness of the Visualizations at conveying the main message and achieving the goals of the project:

- Choose topics that have compelling implications or answer the question “so what”.
- Consider making connections to global warming and climate change more obvious.

The team could consider the following changes to improve “readability” of the Visualizations:

- Allow time at the beginning of the Visualization for viewers to orient themselves to the data being displayed before beginning the captions.
- Label the continents and oceans, especially when using atypical views of the globe.
- Include a line for the Equator rather than labeling the Tropics of Cancer and Capricorn.
- Increase the contrast of colors used in NPP and reconsider the use of grey for areas of no data.
- Interpretation of areas of no data may be needed in NPP since it was common question raised by viewers.
- Use a horizontal bar for the color legends.
- Create additional opportunities for comparing two points in time using multiple globes.
- Move all captions to the bottom of the screen.
- Use real images of conditions “on the ground.” A technique like the picture-in-picture used in Science on a Sphere may be appropriate. Another option is to use a satellite image, like the one in *Global Fires 2002-2008* where smoke from fires in October 2007 is visible from the air.

## Appendix 1: Focus Group Protocol

Thank you all for joining us today. I'm Susan and I'll be leading this focus group for the next sixty minutes. As you heard when we first approached you, AMNH is developing new programs about earth and climate science. The organization I work for, the Institute for Learning Innovation, has been hired by the Museum to help them to learn what their visitors think of this work. You've been asked to be part of this group because you were visiting the museum today. Have any of you participated in a focus group before?

[Adapt to responses] I always like to share some ground rules before I start.

Focus groups bring together people with different backgrounds because they each have something valuable to say. We want to make sure that everyone has a chance to share their thoughts, and that we respect each other's opinions. We are interested in the positive and the negative, so please don't be shy about sharing something you feel might be negative. We want to hear about that, too.

We have about 50 minutes for our discussion and want to use that time as efficiently as possible. You're welcome to any refreshments that you see and feel free to stand up or move around if you need to, we'll keep talking as a group. I'm sure you already figured out by the machines around here that we're recording this session. While I'll do most of the talking, my colleague will also be taking notes and may have some questions for you as well.

1. Okay, I know you've all met me but we haven't had a chance to really learn who's who. Let's get started by quickly going around the room with each of you saying your first name and why you chose to visit AMNH today.
2. As I mentioned a minute ago, the Museum is interested in your thoughts on earth and climate science. So, what comes to mind when you hear those words, "earth and climate science"?
  - a. What are some examples you have recently heard, seen, or read about that would fit in with what the group has just described?
3. I'd like to show you a short video now, and after you've seen it, we'll talk about what you saw.

<Show visualization: Sea Surface Temperature>

4. Well, what did you think about that video?
  - a. What do you think it was about?
  - b. Can you tell me, in your own words, what you **now know** about that topic that you didn't know before?
    - i. [probe another participant] Did you learn something different?
  - c. Who might this be aimed at? (e.g. age, experience/knowledge level)
  - d. Did you need prior knowledge of the topic to understand the video?
    - i. What prior knowledge did you draw from?
5. What interested you the most in the video?
6. What was least interesting?
7. Have you seen videos like this before? Where?

*Transition:* One of the reasons we're doing this is to learn how to improve these videos for people like you. That means that it's sometimes difficult to respond to a film when you've only seen it zip by once. What I'd like to do is spend a few minutes slowly reviewing the scenes to see if that reminds you of what you were learning, or what appeared to be unrelated or vague.

8. I'm going to play it for a bit, and then stop the video and you can tell me what you discovered new, what you didn't see the first time that you wish you had, or what you thought was not that interesting for you, and which parts you'd really like to hear more about. If I don't stop it fast enough or you want to say something, pipe up and yell STOP so we can talk about what interests you [play in chunks]. [after general feedback and probing, make sure to cover specific points below]
  - a. Are you able to tell **where** you are? How about **when**?
    - i. What are the clues that help you? Do they need to be clearer?
  - b. What do you think the color variations mean?
    - i. How helpful are they? What clues did you use to interpret it? (ask specifically about the labels with arrows)
    - ii. Is contrast an issue? How about color blindness?
  - c. What about the placement of the captions? Did that work for you (After seeing both, ask which they preferred: on the globe or at the bottom?)
  - d. What other elements were helpful in making sense of the video? Tell me more about that?
9. Now that you have seen it again, is there anything else the producers could do to improve the video? [after general feedback and probing, move to specific points below]
  - a. What about the pacing? I'll give you 3 options (too slow, just right, too fast)—what do you think, raise your hands. Tell me more about that.
  - b. What about the overall length? Again, 3 choices (too short, just right, too long)—what do you think, raise your hands. Tell me more about that.
  - c. What about the vocabulary? Again, 3 choices (too simple, just right, too difficult)—what do you think, raise your hands. Tell me more about that.
  - d. What about the content? Again, 3 choices (too basic, just right, too basic)—what do you think, raise your hands. Tell me more about that.
  - e. Was there anything that you felt you really needed more information on to make it clearer? What type of information could be provided?

<Repeat questions 4-9 with second visualization: Net Primary Production>

10. Thanks, I just have a few more questions. Tell me, these videos talked about the natural rhythms of the earth's climate and other systems. How do you talk about this topic in your home? How would you talk about this with your friends? [probe and make sure to address men and women in conversation]
11. When you consider all of the video you've seen, how does that make you feel about the Earth?
12. Is there anything that you're taking away from this experience that you think you'd like to pass on to others?

We've reached the end of our time together and you've given us some wonderful ideas to think about. Thank you so much everyone for being so open and sharing so much. I know this will help the Museum revise this work to suit people like you.

On your way out, <ILI NAME> has something to thank you for your help.