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Lasers, Penguins, and Polar Bears: Novel Outreach and Education Approaches for NASA'S ICESAT-2 Mission

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Abstract

NASA's Ice, Cloud, and land Elevation Satellite (ICESat-2), to be launched in 2018, will measure the height of Earth from space using lasers, collecting the most precise and detailed account yet of our planet's elevation. The mission will allow scientists to investigate how global warming is changing the planet's icy polar regions and to take stock of Earth's vegetation. ICESat-2's emphasis on polar ice, as well as its unique measurement approach, will provides an intriguing and accessible focus for the mission's education and outreach programs. Sea ice and land ice are areas have experienced significant change in recent years. It is key to communicate why we are measuring these areas and their importance. ICESat-2 science data will provide much-needed answers to climate change questions such as, "Is the ice really melting in the polar regions?" and "What does studying Earth's frozen regions tell us about our changing climate?" In this paper, Lessons-learned and novel techniques for engaging and educating all audiences in the mission will be discussed, such as including results of a unique collaboration with art design school the Savannah College of Art Design (SCAD) to create fun and exciting products such as animated characters, emojis, and interactive stories. Future collaborations with wildlife researchers, a new citizen science program in collaboration with GLOBE, and evidence from other STEAM (Science, Technology, Engineering, Arts, Math) education approaches will also be detailed in this paper.

Keywords: STEAM, Earth Science, polar regions, lasers, ICESat-2

1. Introduction

NASA's ICESat-2 mission [1] will let scientists and others view the globe in 3-dimensions – adding measurements of elevation to images of our planet. To provide these measurements, however, requires the incredibly precise engineering of the ICESat-2 satellite and its laser altimeter instrument. Time is measured in picoseconds, light is measured in individual photons, and ice is measured in centimeters. Elevation is determined by the time it takes for a laser pulse to be emitted from the satellite, bounce off Earth's surface, and then return to the satellite. Because the speed of light is very well known, this time can be converted into elevation.

To introduce the importance and excitement of such a complex mission to the general public, the ICESat-2 outreach and communications team at NASA is employing several different strategies and approaches. The team has developed hands-on exhibits to explain concepts including laser altimetry and sea-ice melt. We have created the ICESat-2/SCAD Collaborative Student Program to bring young, visually creative ideas to outreach efforts, including animated mascots. We continue to work with NASA's social media team to keep up with the latest ways of reaching new and changing audiences.

As the mission nears its launch date, and as the satellite starts collecting data, we will continue to evolve new methods of engaging the public to share ICESat-2's novel engineering that allows us to gather data to answer essential science questions.

1.1 Polar Regions Matter

The warming temperatures of a changing climate are already impacting the Arctic – sea ice cover is decreasing and glaciers in Greenland and elsewhere are retreating. But for many people the polar regions are "out of sight, out of mind." They don't understand that changes in Earth's icy regions can impact the rest of the planet, with impacts including sea level rise, changing weather patterns, and decreased habitat for wildlife. ICESat-2 will gather data – such as the change in

elevation of glaciers and ice sheets, and the above-water height of sea ice – that will help scientists better understand these developments. To help people understand these changes, as well as how ICESat-2 will measure them (see Fig. 1), the outreach and communications team will employ new as well as tested methods.

Fig. 1. ICESat-2 will use six laser beams to measure the height of ice and other ecosystems. Illustration credit: ICESat-2/SCAD Collaborative Student Project

1.2 Goals

One goal of ICESat-2's outreach and communications efforts are to reach new audiences that would not normally gravitate to science, engineering, or Earth science or climate change. Especially important is to engage young people, especially girls and minorities.

1.3 Lasers, Polar Bears, and Penguins

The ICESat-2 mission has several features that naturally grab people's attention – it uses lasers to gather data, and it studies areas with charismatic megafauna such as penguins and polar bears. The team will create visuals and interactives that involve lasers, and will use the bright green color of ICESat-2's laser beams in products such as our website and informational brochure. The SCAD partnership has even created two mascots for the mission – a bright green photon called "Pho", and a friendly penguin named "Paige." (See Fig. 2.) The mission is also planning a partnership with a wildlife organization dedicated to studying polar wildlife, since data collected from ICESat-2 will be used to study changes in their habitats.

Associating the mission with easily accessible elements, like lasers and charismatic animals, could help engage the public with ICESat-2 and polar science. An article [2] about a scientific study published in the Journal of Environmental Education [3] states: "the study suggests that people appear more willing to take action if the perceived threat involves some kind of beloved creature other than them. And the reason is that, at least when it comes to climate change, people seem more motivated by empathy for non-human others than their own self-interest."

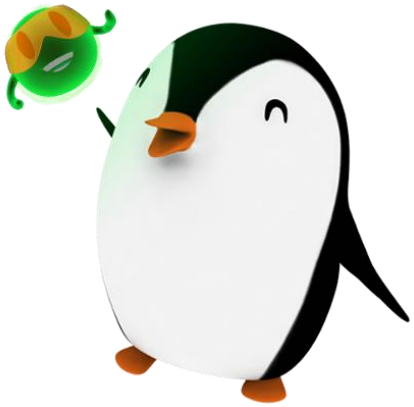

Fig. 2. Pho and Paige, two characters created by the ICESat-2/SCAD Collaborative Student Program.

2. Evidence from other STEAM programs

It is becoming widely recognized that integrating the arts into science and STEAM approaches are a powerful way to increase participation in STEM, and improve attainment of STEM-related skills [4]. In addition, it has the power to attract and inspire diverse audiences, and help students understand and learn more concepts. Research found that students who study the arts, outperform their non-arts peers on mathematics assessments [5,6,7]. Students who study the arts also score higher than their peers on tests measuring the ability to analyze information and solve complex problems, and are more likely to approach problems with patience and persistence [8,9].

Informal education provides opportunities to educate audiences by first connecting with their own interests, which in many cases may not be science or math but which may well be the arts. Art can be a powerful tool and gateway to inspiration and motivation to learn more about the Earth Sciences, as well as communicate on an emotional level. One successful example of using the arts to introduce Earth science is the NASA-funded Beautiful Earth: Experiencing and Learning Science in a New and Engaging Way Project [10]. The program uses art and music to make an emotional connection to our home planet and provide a different mechanism to learning. It features a multi-media musical and visual live program (Bella Gaia) [11] with NASA imagery of Earth from space and data visualizations, discussions with a NASA Earth Scientist, and hands-on experiments [12,13,14,15]. It aims to inspire and engage students and teachers with NASA

Earth science through a unique multi-pronged approach through the heart, head, and hands. Sample video clips here:
http://beautifulearth.gsfc.nasa.gov/index.php?section=29,
http://beautifulearth.gsfc.nasa.gov/index.php?section=19

External evaluator pre- and post- survey data of participants experiencing the program across 4 partner sites between 2012 and 2013, demonstrated a significant impact on participants' perceptions, learning and interest in STEM [16,17].

External evaluation data found that Beautiful Earth created a dramatic increase in audience interest in and understanding of Earth and Earth Sciences. The program has a wonderful record of raising interest in and love for Earth and space among all populations and ages and also successfully incorporated an indigenous component (NEW - Native Earth Ways) for outreach to Native American communities as outlined in the final report of this project [18], which stated that "more than 95% of the participants reported that their understanding and knowledge of Planet Earth had changed, increased and improved, as a result of participating in Beautiful Earth." Additional success was seen after a NEW workshop in Oregon with the Chemawa Indian School, where several students asked how they could pursue a NASA career. Combining art and science has proven to be a way to inspire and create an emotional connection to the material as well as bring in diverse audiences.

The ICESat-2 outreach program intends to utilize the Beautiful Earth program to inspire and communicate the mission's science as well as to develop collaborative programs with Native American communities.

3. Novel Outreach Programs

3.1 Art Student collaboration

Following the idea that art is a powerful tool to inspire and communicate science, the ICESat-2 mission teamed up with students and faculty from the Savannah College of Art and Design (SCAD) and Bowling Green State University (BSGU) in order to develop and produce a series of assets to be used for the mission's public outreach and educational purposes. The ICESat-2/SCAD Collaborative Student Program (2013-2016) was led by Helen-Nicole Kostis (NASA Goddard Scientific Visualization Studio). Students were handpicked by faculty for their skills, creativity and work ethic. They were offered a blank slate at the beginning of the collaboration. The students' task was to translate intricate and highly technical language into different products like short films, bookmarks, etc. to excite and educate the public – especially people who were not science aware - on how ICESat-2's data will impact and broaden the understanding of our planet's changing ice.

3.1.1 SCAD Collaborative Program

As part of SCAD's Collaborative Learning Center (CLC) program, a partnership was formed between the mission and the college in order to offer students a real-world experience creating novel products for the client, ICESat-2. Several different assets were created, including short films, character designs, emojis and more. Two of the major products developed were:

- **'Photon Jump'**, an animated short film featuring Pho the photon as he travels from the satellite down to the surface of the earth and back. (See Fig. 3.)
- **Paige the Intern**, still in production, a digital pop-up book starring a penguin named Paige. Her job as an intern will help explain the entire process behind the mission, from concept to deployment and beyond. (See Fig. 4 and 5.) Paige the penguin, a friendly polar animal character, will help people connect to the mission.

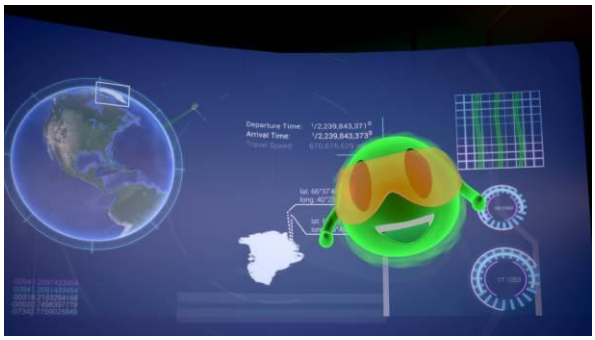

Fig. 3. Screen shot from 'Photon Jump.' The audience will follow Pho the photon as he travels from ICESat-2 down to earth and back, thus measuring the height of ice.

Fig. 4. Paige the Penguin as intern, development sketch.

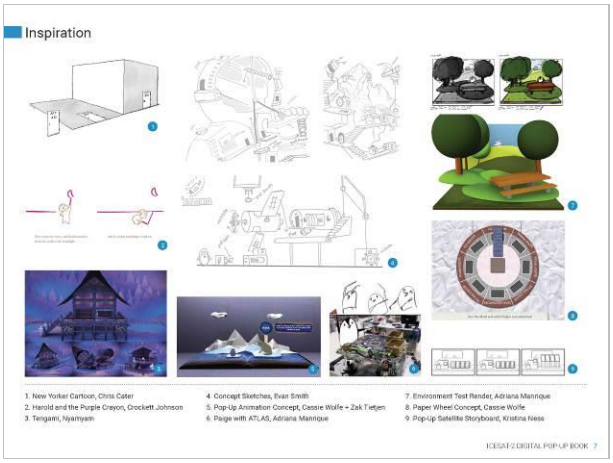

Fig. 5. Preproduction sketches and development for Paige the Intern Popup book.

3.1.2 Results/Lessons Learned

Other program results include the development and production of several outreach and communications products including bookmarks (see Fig. 6), posters (see Fig. 7), banners, and a website, as detailed in the publication in press [19]. Approximately 35 students and three professors from SCAD were directly involved in the program. From BGSU, there were approximately 30 students and two professors involved over two semesters. In addition, 22 student internships were created in the product production phase.

As an additional result of this program, one of the students, (Co-author Adriana Manrique), was hired as outreach specialist/animator into NASA Goddard's Conceptual Image (CI) Lab to continue working on ICESat-2 outreach as well as other NASA missions.

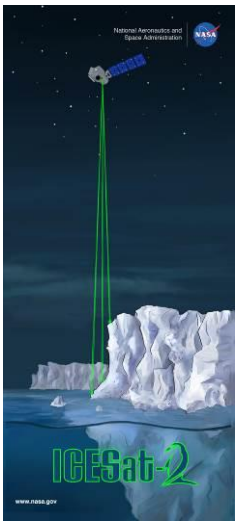

Fig. 6. 3D Lenticular and 2D bookmarks were designed to be used with a number of outreach and educational activities.

Fig. 7. Poster showing the different Biomes that ICESat-2 will be able to measure.

One of the challenges for this program was the teleworking element. Students, faculty and ICESat-2 team members were at the time scattered around the U.S. Communication proved to be difficult sometimes. A strict schedule for reviews, constant feedback and a range of channels of communication helped the production stay on course. The role of the faculty and the ICESat-2 Collaborative Program Manager was important to help guide and ensure a superior product.

Students had different skill sets that provided a well-rounded team. The student teams consisted of a mix of experienced upperclassmen with lengthy experience in production environments and collaborative projects and students who had not had the chance to experience those settings. Often with the aid of the more experienced students, faculty had to reign in the rest of the group in order to keep the production process under control.

Thanks to the outstanding results from this partnership, the ICESat-2 mission now has a wealth of concepts to pull from to develop a series of products dedicated to educate and reach the public on ICESat-2's mission.

Student participants also greatly benefited by learning about and becoming inspired by a NASA Earth Science mission. They also learned the production process and how to work with a client.

3.1.3 Future endeavours

We will implement other ideas created from the ICESat-2/SCAD Student Collaborative program such as mascot emojis, the Digital Pop-up Book developed by BGSU students, with Paige the penguin as the main character.

3.2 Citizen Science and Student Data Collection with GLOBE

The GLOBE Program is an international program, founded in 1996, designed to allow students and citizen scientists from across the world to engage in hands-on measurements relating to our Earth's environment. The

GLOBE Program utilizes measurement protocols in the Atmosphere, Hydrosphere, Biosphere, Pedosphere, and the Earth as a System. More recently, the GLOBE Program has teamed up with NASA satellite missions so that participants can learn how NASA scientists study the environmental conditions contained in the GLOBE Program protocols. The GLOBE participants can also provide highly valuable in-situ data that can be used for satellite data validation.

For ICESat-2, we are entering into a partnership with the GLOBE Program by modifying several of the existing protocols, namely the GPS protocol and the Measuring Tree Height Using the Simplified Clinometer Technique protocol. These existing protocols fit well with ICESat-2's mission to measure the height of our planet. We have modified the existing protocols to create a GPS Base ICESat-2 Study Site, and modified the Tree Height protocol to include building heights as well, bringing in the urban environment. These measurements will allow the participants to focus on a particular area, while allowing the ICESat-2 scientists to use the data for ICESat-2 satellite data validation. GLOBE Program participants can then compare their data to data around the world and interact with NASA ICESat-2 scientists [20].

3.3 Hands-on Activities, Experiments, and Measurements

3.3.1 The ICESat-2 Bouncy Ball Photon Collection Activity

ICESat-2 will provide scientists with height measurements that create a global portrait of Earth's 3rd dimension, gathering data that can precisely track changes of terrain including glaciers, sea ice, forests, buildings and more. These measurements will be taken using Light Detection and Ranging (LIDAR), a detection system that works on the principle of radar, but uses light from a laser. When the laser photons leave the ICESat-2 satellite on their way to Earth, the large majority of them are lost as light is scattered, absorbed, reflected, etc. The purpose of this activity is for participants to see just how many bouncy balls or "photons" they can collect after bouncing them off the surface. This activity utilizes many different surfaces to represent ice, vegetation, and buildings. Participants act as the ICESat-2 satellite and drop ten green bouncy balls at once, and try to catch as many as they can. Each ball caught represents 10% of the returned photons. (See Fig. 8.)

Fig. 8. Students participating in the ICESat-2 Bouncy Ball Photon Collection Challenge at the NASA Wallops Visitors Center.

3.3.2 Sea Ice Towers

The Sea Ice Towers Activity is designed for the younger student. This activity allows students to explore sea ice coverage in the Arctic around the North Pole. Students begin by examining some satellite images of the Arctic sea ice for several different years. The students then use small, plastic blocks to build a type of 3D histogram, in order to see how the sea ice area has changed over several years. After the students build the towers and make observations of the sea ice amount (see Fig. 9), they can have a discussion as a class or in smaller groups to discuss what they noticed from year to year. Extensions include various NASA videos, visualizations, and animated datasets to prompt more observations and discussion.

Fig. 9. Students at the Montgomery Knolls Elementary school in Silver Spring, MD build 'sea ice towers'

3.3.3 "Motion in the Ocean"

The "Motion in the Ocean" experiments were developed under the Beautiful Earth program. These experiments are intended to demonstrate fluid densities and movement in our oceans by placing fresh water on top of salt water or vice versa. By understanding how water moves in our oceans, it allows us to see the interconnectedness of water in the Earth system during

normal environmental conditions to conditions that are dynamically changing due to a climate change response.

As part of these experiments, a discussion of our planet's thermohaline circulation is vital to understanding our planet's response to change (i.e., ice melt, increased sea surface temperatures). Sea ice is a big driver for the thermohaline circulation (see Fig. 10.) because when sea ice freezes, it releases salty water, which then sinks to the bottom. This concept is key to understanding Earth's global climate system.

This hands-on experiment encourages teamwork and has been highly popular and successful at Beautiful Earth and other education events (over 20 events) both informal and formal. Math is brought into this experiment through measuring the time it takes for fluid transport to occur depending upon the temperature or salinity gradient. Student groups can perform the experiment with different amounts of salt and different fluid temperatures and measure the reaction.

Students work in teams to dye and mix salt and fresh water, and cold and hot water, and load them into a used tennis ball tube (a nice way to recycle) (see Fig. 11 and 12). Students predict what will happen based on their previous lesson with the global thermohaline circulation system, which includes viewing the stunning scientific visualization from NASA's SVS*.

This experiment was developed by Native American educator, Jim Rock (Dakota) and Beautiful Earth Collaborator, and further refined by PI Casasanto, and NASA Cryospheric Scientist and Co-author, Dr. Thorsten Markus. This experiment will be used as a powerful hands-on activity as a follow-on to understanding the dynamics of the ocean and what happens if the sea ice melts.

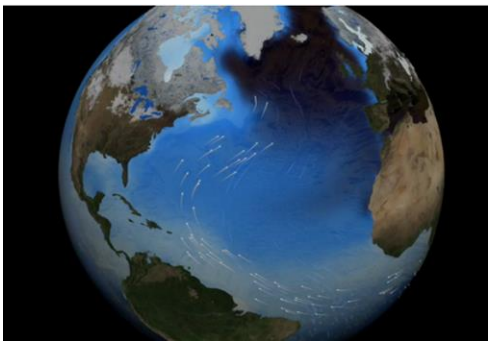

Fig. 10. NASA SVS Thermohaline Circulation - Great Ocean Conveyor Belt Visualization

* http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=3658

Fig. 11. Onandaga Nation students at Syracuse, NY Milton J. RubensteinMuseum of Science & Technology performing experiments with tennis ball tubes during a Beautiful Earth event, October 2011.

Fig. 12. High School girls experiment in teams at Texas A&M University during a Beautiful Earth event at the International STEM Alliance Fair, Laredo, TX.

3.3.4 The Icing on Greenland

Much of our fresh water is locked up in ice. After the Antarctic ice sheet, the continent of Greenland is the second largest ice body in the world. In order to see how much ice is on Greenland, we will use data from NASA's ICESat Satellite (Ice, Cloud, and land Elevation Satellite), which took measurements of Earth's elevation from space between 2003 to 2009. It collected enough data to map the continent of Greenland.

In this activity, students use crayons or markers to make their own color map of the ice on Greenland, using actual numbers from the ICESat satellite. Once the map is colored completely, students will then discuss what the colors mean, particular pattern in the colors, and what this means for the ice on Greenland.

3.3.5 Altimeter exhibit

The ICESat-2 Outreach members have teamed up with engineers at the Oregon Museum of Science and Industry (OMSI) to plan, develop, and build the ICESat-2 Altimeter Exhibit. This exhibit has a mock-up satellite that runs on a track, fifteen feet above the ground. As the satellite moves along the twelve-foot long track, it uses an onboard system to measure the elevation of anything underneath it. Observers can stand under the

satellite and have their heights measured (see Fig. 13). An exhibit screen shows the heights in real-time. This exhibit is meant to showcase what the ICESat-2 satellite will do when it is flying in space. The exhibit uses a benign ultrasound instrument, rather than a laser, due to the close nature of the mock-up satellite to the observer. Along with the measurements, the exhibit has onscreen features about ICESat-2, developed with the NASA eClips Program.

Figure 13. Children stand under the ICESat-2 satellite model to have their height measurements taken at the U.S. Science and Engineering Festival.

4. Results/Lessons Learned

Audience reactions and interactions have been very positive to the products and activities. People are generally surprised at the rate of ice change and that NASA is measuring ice, and they are open to learning more. Students ask what they can do to become better environmental stewards. Test school audiences for the Photon Jump animation have resulted in much laughter, and kids wanting to see more.

Students love putting blocks together, and through the sea ice towers activity can visually see the amount of Arctic ice change. As a facilitator, it has been difficult to explain all the various concepts of global warming, importance of ice for our planet, through this one activity. In the future, we will organize different groups to look at different aspects of the ice and then compare and contrast and draw their own conclusions.

The outreach team will utilize lessons-learned from existing activities and further refine them to have greater impact. New products and partnerships will be developed to enhance our outreach efforts and ways to communicate the complex science of the mission.

5. Conclusions

Overall, using art and STEAM approaches, hands-on interactives, and on-the- ground data collection are powerful tools to attracting, educating, and involving diverse audiences.

The ICESat-2 mission will be a wonderful platform to explore these outreach techniques and to engage audiences further in our mission from launch to orbit, to data collection, to ground validation, and beyond.

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