NASA Earth Science Education Collaborative

NASA Science Mission Directorate Science Activation Program

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Table of Contents

I. Accomplishments

A. Major Goals, Activities, and Objectives

Goal

NESEC's goal is to enable broad participation in authentic NASA Earth STEM experiences by learners throughout their lives. We do this by creating meaningful experiences and resources that are based on NASA Earth assets (science, data, and subject matter experts) and partnering strategically with external organizations (not funded by this award) to deliver NESEC project experiences and resources broadly across the U.S.

Activities

From 2021 to 2026 the cross-organizational NESEC team carried out activities, drawing on each partner's strengths, related to the following three interconnected areas:

- **GLOBE Observer (pages 8-17)**. Using the GLOBE Observer mobile app and supporting resources, the team engaged citizen scientists of all ages to take observations in support of NASA Earth system science. These observations help interpret and complement NASA satellite data. Observations from 2021 to 2026 included GLOBE Observer Clouds, Land Cover, Mosquito Habitat Mapper, Trees, and a temporary Eclipse tool for the 2023 and 2024 solar eclipses.
- **Science Investigations with NASA (pages 18-47),** creating and offering STEM experiences for learners and educators to engage with NASA STEM assets: science, data and subject matter experts (SMEs). STEM experiences included those for learners and educators in formal and out-of-school settings. These ranged from short-term experiences that can increase awareness of and spark interest in NASA Earth STEM to longer-term experiences and learner-defined research projects with the potential to impact learners' science identity and career path.
- **Strategic Partnerships and Collaborations (page 48)** enabled NESEC to deliver NASA Earth STEM experiences and assets to larger audiences. Our partners and collaborators ranged from large national and international organizations and programs (e.g., Civil Air Patrol, SciStarter, American Camp Association, Polar Citizen Science Collective, the GLOBE Program) to regional and local community partners (e.g., North Carolina Arboretum, Queens Public Library, Los Angeles Public Library, and individual libraries and camps). NESEC also leveraged numerous SciAct cross-collaborations to have a greater impact.

Figure 1 (page 4) provides an overview of NESEC activities and Table 1 (page 5) identifies NESEC major accomplishments in support of SciAct Mid-Level Objectives.

Figure 1: NESEC Overview

Table 1. Overview of NESEC Accomplishments Supporting SciAct Mid-Level Objectives

SciAct Mid-Level Objectives	NESEC Accomplishments
MLO 1a: Inspire participants' interest in STEM and the development of their identities as science learners	During SciAct 2.0 our work inspired interest in STEM from a wide array of audiences and learners of all ages including children attending summer camps, Civil Air Patrol cadets, libraries and their patrons, informal and formal educators. ● Partnered with the Civil Air Patrol in the Aviation Weather Mission that reached thousands of cadets who participated in collecting atmospheric and aviation data related to contrail formation. Evaluation results **indicate increases in interest in science and engineering following participation** in this program. ● Partnered with **150 public libraries** from across the nation to bring science programming associated with the 2023 annular and 2024 total solar eclipses. Programs catalyzed learning and interest in science (especially eclipses) in learners of all ages. ● Provided **virtual 8-week summer internships for high school students** in the SEES Earth System Explorers. Interns report **increase in interest in science careers**.
MLO 1b: Provide opportunities for participants to engage with the disciplinary content related to NASA science and engineering.	NESEC cultivated numerous pathways for learners to engage directly with NASA science, data, and SMEs. ● GLOBE Goes to Camp included more than **70 participating camps that engaged 115,00 campers and their families in NASA STEM.** ● **834 Girl Scout Troops** and an **additional 4,899 individual scouts** selected GLOBE Observer for their Think Like a Citizen Scientist journey. ● The Regeneron International Science and Engineering Fair (ISEF) **NASA Earth System Science Award recognized more than 650 students.** ● More than **400 U.S. public libraries engaged** patrons in programs using NESEC resources, including GLOBE Eclipse (2023 and 2024) and NUBE Clouds Game (2025). A significant number of these libraries (>50%) serve rural communities. ● The Trees Around the GLOBE Student Research Campaign and GLOBE Mission Mosquito provided more than **100 webinars for educators and learners** that connected them to NASA SMEs and prepared them to participate in student research using GLOBE and NASA satellite data using online tools that included Open Altimetry, NASA WorldView, Collect Earth, My NASA Data, Google Earth Engine, and ArcGIS Story Maps. ● GLOBE International Virtual Science Symposium included **more than 300 IVSS projects** that were either mentored by NESEC team members or participated in NESEC campaign webinars.

SciAct Mid-Level Objectives	NESEC Accomplishments
MLOS 2a Advance participants' understanding of the process of science using NASA SMD assets	● Engaged thousands of Civil Air Patrol cadets in the science practice of collecting data, and measured changes in skills associated with data collection. **90% of cadets (n=104) reported developing a greater understanding of the importance of data accuracy in scientific investigations.** ● Delivered an innovative, virtual internship model – SEES Earth System Explorers – that engaged **349 high school students and 45 peer mentors (2021-2025) in scientific research** involving all stages of the data life cycle: field data collection, data ingestion into data tools, data exploration, visualization and analysis, and documentation/archiving data products. Interns built skills related to issues and practices associated with open science and the functionality and benefit of teamwork in science research. ● Developed and led a webinar series for teachers in collaboration with the GLOBE Mission Earth SciAct project to prepare teachers to guide students' research on collecting data during the 2024 total solar eclipse. Teachers reported on a pre-post survey **increases in confidence in guiding student research**, helping to create student scientific posters, and helping students submit research projects. ● Further evidence of the authenticity and value of NESEC Science Investigations is that these initiatives have generated valuable scientific information. A total of **45 peer-reviewed papers have been published or accepted for publication** in journals (Appendix A provides a full list of publications).
MLO 3a: Increase participation in learner-centered experiences based on NASA SMD assets	NESEC leveraged numerous NASA Earth science assets – science, people, and data – to provide multiple entry points for learners to utilize these assets through designed activities and structured engagement opportunities that provide participants with authentic opportunities to engage in science. ● NESEC used NASA Earth observation data as part of several activities engaging learners to investigate Earth system science phenomena as part of data collection challenges, GLOBE field campaigns, student internships (e.g., SEES Earth System Explorers and internships at NASA Centers), learning resources and experiences (e.g., webinars, workshops, and tutorials, and presentations on using NASA Earth observation data products) are grounded in NASA science. ● By the end of 2025, more than **300,000 individuals had joined GLOBE as citizen scientists**. From 2021 to 2025, these citizen science volunteers collected nearly **1.2 million environmental observations** of clouds, mosquito habitats, land cover and trees through the

SciAct Mid-Level Objectives	NESEC Accomplishments
	GLOBE Observer app, which represents more than **100,000 volunteer hours** in supporting NASA science through GLOBE Observer during NESEC's lifetime. ● More than **200,000 learners and educators participated** in our science investigations, including GLOBE Campaigns, CAP NASA Missions, GLOBE Goes to Camp, Libraries, SEES ESE internship, ISEF Earth System Science Award. ● NESEC engaged more than **225 subject matter experts** (SMEs) from 2016 to 2026.
MLO 4a: Leverage internal mechanisms to support sharing and learning across the Science Activation portfolio.	● NESEC team members participated fully in the SciAct community of practice, learning from other SciAct projects, sharing our expertise, and collaborating on products, activities, and events. Collaborations ranged from co-designing or co-delivering learning opportunities and resources, sharing knowledge or resources, and dissemination. ● NESEC has completed successful **cross-collaborations with 22 SciAct teams**, with 15 signed statements of collaborations, plus numerous ad hoc collaborations (e.g. coordinating SciAct participation at the 2025 Conference for the Advancement of Participatory Sciences, reviewing and providing feedback on NASA Citizen Science Librarian Starter Kit). ● The results of an annual external partner survey shows that all Science Activation partnerships strongly agreed with statements that their **partnership with NESEC is beneficial and NESEC meets the needs of its partners**. For example, one SciAct partner noted that their partnership with NESEC has "elevated the impact" of their own program while another SciAct partner commented on the strong working relationship that is built through "similar goals and developed trust."
MLO 4b: Utilize external partners to leverage reach and effectiveness of the Science Activation portfolio.	NESEC has cultivated a robust partnership ecosystem spanning SciAct teams, NASA entities, subject matter experts (SMEs), and educational and community organizations. ● From 2021–2024, annual partner surveys and social network analyses consistently show **high trust, effective collaboration structures, and meaningful shared impact.** ● NESEC's partnerships engaged a **wide range of audiences**, including K–12 students, teachers, librarians, camp staff, families, professionals, and citizen scientists. Partners consistently highlight NESEC's tools and resources as impactful.

SciAct Mid-Level Objectives	NESEC Accomplishments
	• Adaptability and resilience: During the COVID-19 pandemic, partners reported significant disruptions but emphasized NESEC's strong adaptability, virtual resource development, and commitment to continuity. NESEC's ability to maintain high collaboration quality during crisis conditions reflects the strength of its partnership model.

B. GLOBE Observer

Significant Accomplishments

Between 2016 and 2025, NESEC built a successful citizen science community around GLOBE Observer, the app of the GLOBE Program. GLOBE is an environmental science and education program that engages educators, students, and individuals in collecting environmental data in support of NASA Earth Science. Following are significant achievements during SciAct 2.0, which are described in the following text.

1) Volunteer Engagement in Contributing to NASA Earth Science
2) Connecting Earth Science to the Eclipses
3) Focused Engagement Through Data Collection Challenges
4) Partnering with Artemis for the NASA Moon Trees Quest
5) GLOBE Observer App Development
6) Expanding Connections to NASA Satellite Data

1) Volunteer Engagement in Contributing to NASA Earth Science

By the end of 2025, more than 300,000 individuals had joined GLOBE as citizen scientists. These citizen science volunteers collected nearly 1.2 million environmental observations of clouds, mosquito habitats, land cover and trees through the GLOBE Observer app. Assuming each observation takes approximately five minutes, volunteers engaged 100,000 hours in supporting NASA science through GLOBE Observer during NESEC's lifetime.

Most of the data collected were clouds data, with more than 965,000 observations submitted since 2016. More than 48,000 mosquito habitat observations, 60,000 land cover observations, and 127,000 tree height observations were submitted. Figures 2 and 3 show a largely steady rate of data submission over time with some step jumps. These rapid gains mostly correlate with focused engagement events including data collection challenges and eclipses.

Figure 2. GLOBE Observer Clouds Data Growth

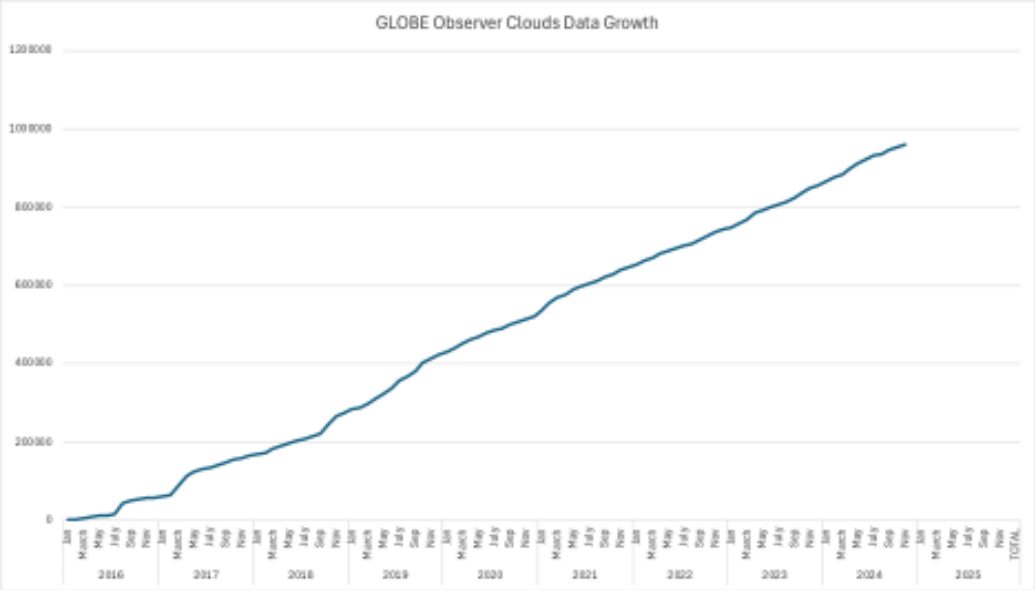
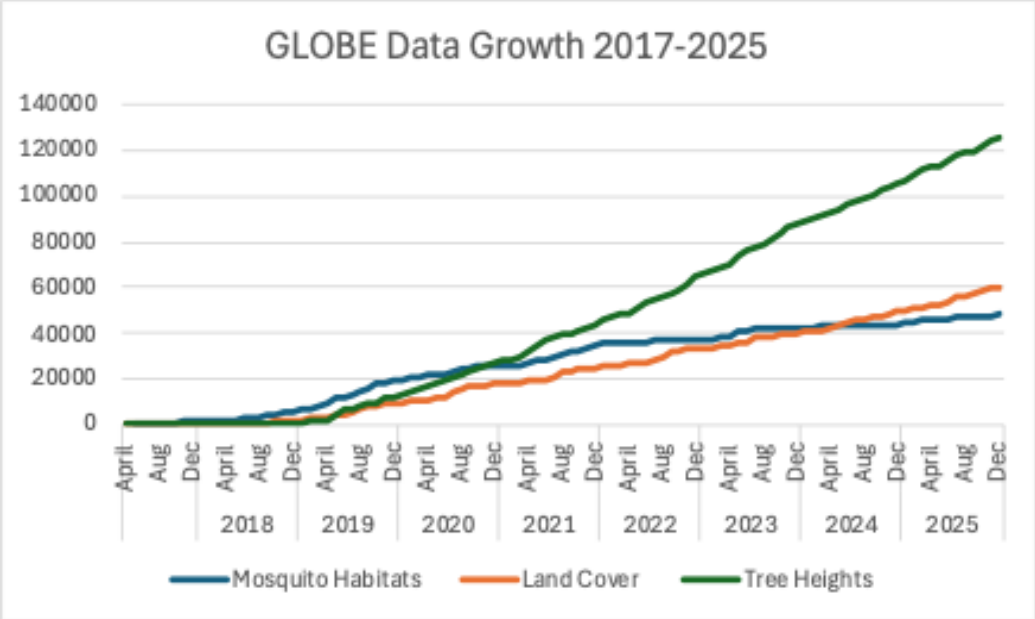


Figure 3. GLOBE Observer Mosquito Habitat, Land Cover, and Trees Data Growth



2) Connecting Earth Science to the Eclipses

The eclipses of 2023 and 2024 were significant engagement initiatives to expand and engage a community of citizen scientists around GLOBE Observer. NESEC focused efforts on GLOBE Observer Eclipse in 2023-2024 to achieve the following objectives:

- Use the annular and total eclipses to engage new and diverse audiences in NASA Earth science with an emphasis on the Sun-Earth connection and Earth's energy budget.

- Engage a wide range of community partners to recruit and support a volunteer community
- Collect cloud, temperature, and land cover data to support student and scientific research associated with eclipses.

We made efforts to recruit individual volunteers through social media and NASA communications, but we expended more energy in developing partnerships with community-based organizations and educators to engage volunteers. We did this to provide a local center for volunteers to get support and build connections to other volunteers. We hoped that this type of community would create structures to encourage long-term engagement with collecting data using the GLOBE Observer app. Partner organizations ranged from other Science Activation projects to organizations like libraries, Civil Air Patrol, and Master Naturalists as shown in Table 2.

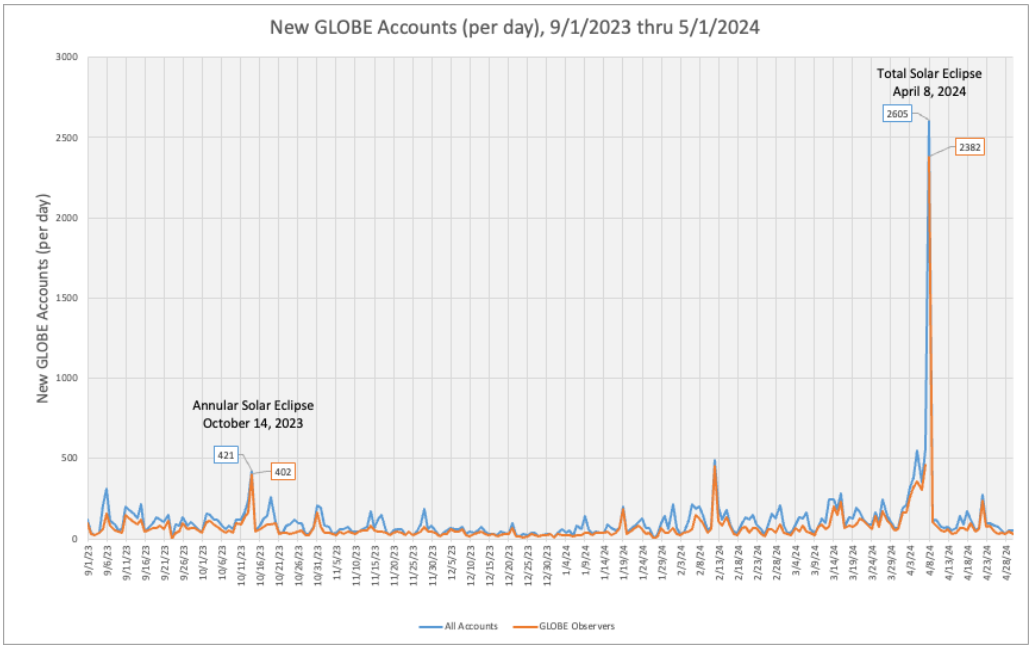
Table 2. GLOBE Observer Eclipse Partnerships

Partner	Materials	Digital Dissemination	Training to Partner	Co-hosted Training to a Shared Audience
NASA@MyLibrary	☑	☑	☑	☑
NASA Sun Spots	☑	☑	☑	☐
The GLOBE Program	☑	☑	☑	☐
NASA Heliophysics Education Action Team (HEAT)	☐	☑	☐	☑
SciStarter	☐	☑	☐	☑
Eclipse Ambassadors	☐	☑	☑	☐
Earth to Sky	☐	☑	☑	☐
Museum and Informal Education Alliance	☐	☑	☑	☐
Solar System Ambassadors	☐	☑	☑	☐
GLOBE Mission Earth	☐	☑	☐	☑
NASA Citizen Science	☐	☑	☑	☐
NASA Communications	☐	☑	☑	☐
National Informal Learning STEM Network	☐	☑	☑	☐
Learning Ecosystems Northeast (GMRI)	☐	☑	☑	☐
National Eclipse Ballooning Project	☐	☑	☑	☐
NOAA Science on a Sphere	☐	☑	☐	☐
American Camp Association	☐	☑	☐	☐
NASA Eclipse Soundscapes	☐	☑	☐	☑
NASA eClips	☐	☑	☐	☐
Libraries	☐	☐	☑	☐
Texas Master Naturalists	☐	☐	☑	☐
Civil Air Patrol	☐	☐	☑	☐
STEM Enhancement in Earth Science		☐	☑	☐
GLOBE Goes to Camp	☐	☐	☑	☐
HBCU Network	☐	☐	☑	☐

We created 18 unique products, including videos, guides, activities, display materials, data sheets, and more, to support eclipse engagement in 2023 and 2024. These materials are available in the Eclipse Toolkit on the GLOBE Observer website.

Eclipse efforts succeeded in bringing new volunteers to GLOBE as shown in Figure 4.

Figure 4. New GLOBE Accounts Created Between September 1, 2023, and May 1, 2024



New GLOBE accounts created per day between September 1, 2023, and May 1, 2024. This period covers several social media engagements and two challenges or events - the annular and total solar eclipses. The events generate large spikes in new volunteers. NASA flagship social media accounts featured GLOBE on March 15 and April 3, 2024. Both dates show an increase in account creation. GLOBE ran a social media campaign sending valentines to 40 different organizations, including NASA, NOAA, NSF, and other partners. This campaign is correlated with a significant spike in new users. Graph courtesy GLOBE Data and Information System Team.

3) Focused Engagement Through Data Collection Challenges

In addition to the eclipses, NESEC hosted eight focused periods of engagement in the form of data collection challenges during SciAct 2.0. Challenges are invitations to volunteers to collect specific GLOBE Observer data in a designated time period. They were designed to recruit and engage volunteers around a clear science objective. All challenges increased data collection largely because of focused communication and community engagement demonstrating the power of the GLOBE network in collecting a large volume of ground-based data (Colón Robles, et al., 2020). Challenges were also a significant driver in bringing new volunteers to GLOBE and in engaging the existing community.

All challenges included a social media campaign, new GLOBE web content, and distribution through partners. We also created an activity tracker with a variety of ways for people to be part of some challenges.

Challenges held between 2021 and 2025 include:

- Community Trees Challenge: Science is Better Together

  The Community Trees Challenge: Science is Better Together was held April 15 - May 15, 2021. This challenge featured an activity tracker with a variety of ways for people to be part of the challenge, including by observing tree heights with GLOBE Observer. The challenge resulted in 2,441 tree height observations from 1,733 global locations--a significant increase in the rate of data collection for trees, and at the time, represented 7 percent of tree height data in the GLOBE system.

- Mosquito Habitat Photo Challenge

  The Mosquito Habitat Photo Challenge ran July 25 through August 25, 2021 and was designed in collaboration with Dr. Ryan Carney at the University of South Florida. He needed a variety of mosquito larvae photos to train an image recognition system to classify mosquito larvae.

  We produced a photo guide and a photo tips handout to get usable photos along with an activity tracker developed in collaboration with the Los Angeles Public Library. The library provided Spanish, Armenian, Chinese, Japanese, Korean, Persian, and Russian translations, making this the only activity guide available in multiple languages. This challenge also featured a data dashboard to track data collected in real time and to provide the data to science partners quickly. Just under 1,000 mosquito observations were submitted - a substantial increase from the baseline. We also received 690 land cover observations.

  The science work associated with the challenge was initially published in:
  Carney, R., Mapes, C., Low, R., Long, A., Bowser, A., Durieux, D., et al. (2022). Integrating Global Citizen Science Platforms to Enable Next-Generation Surveillance of Invasive and Vector Mosquitoes. Insects, 13(8), 675. https://doi.org/10.3390/insects13080675

- Cloud Challenge 2022: Clouds in a Changing Climate

  Held January 15 - February 15, 2022, the Cloud Challenge 2022: Clouds in a Changing Climate followed the previous spring, fall, and summer challenges to collect winter data. Cloud Challenge 2022 offered two ways to participate: collect Clouds data during a satellite overpass or classify clouds in photos in the GLOBE CLOUD GAZE Zooniverse project. The goal was to make 20,000 satellite comparisons during the challenge. We connected this challenge to the launch of GOES-T, which eventually became one of the satellites used in the Clouds satellite comparisons. We also created a dashboard for this challenge. The challenge resulted in more than 41,000 observations and 49,455 satellite comparisons (as a single observation may be compared to data from more than one satellite).

- Land Cover Challenge 2022: Land Cover in a Changing Climate

  The Land Cover Challenge 2022: Land Cover in a Changing Climate ran July 26 through August 26, 2022. It maintained the "changing climate" theme from the Clouds challenge earlier in the year. This challenge was connected to the 50th anniversary of the Landsat satellites and focused on tracking change over time. We asked volunteers to submit 25+ observations. Those who submitted 25 observations received Landsat material in the mail. Those who submitted 50 observations received additional material. Participants were also invited to participate in Camp Landsat, a series of online activities offered throughout the summer. As shared in the challenge summary news story, the challenge resulted in just over 1,600 land cover observations. 22 volunteer observers collected more than 25 land cover observations, and 12 of those volunteer observers collected more than 50 observations.

- Trees Challenge 2022: Trees in a Changing Climate

  The Trees Challenge 2022: Trees in a Changing Climate wrapped up the *changing climate* series of challenges in 2022. Held October 11 through November 11, 2022, the challenge simply asked for tree observations. We held a kick-off webinar with the L.A. Public Library on October 11. Through SciStarter, who featured GLOBE Trees in a SciStarter Live event, we invited Girl Scouts to participate in the challenge as part of the Girl Scout Tree Promise, the Girl Scout Climate Challenge, or the Think Like a Citizen Scientist Journey. The challenge resulted in 4753 observations from 754 unique participants (see the news summary).

- Where is the Water? A GLOBE Observer Data Challenge

  Where is the Water? A GLOBE Observer Data Challenge was held May 1 through May 31, 2023. We asked people to collect land cover observations of water edges, particularly in places where surface water is tough to identify in satellite data, such as under vegetation. We also asked that people do a mosquito habitat observation at that site to document whether or not mosquito larvae were present in the water. We received 616 land cover observations and 299 mosquito observations, as shown in the challenge data dashboard.

- GLOBE Eclipse Challenge: Clouds and Our Solar-Powered Earth

  Held March 15 - April 15, 2024, the GLOBE Eclipse Challenge: Clouds and Our Solar-Powered Earth was designed to collect cloud data complementary to data collected during the April 8 total solar eclipse in North America. Participants were asked to collect observations at varying times of the day to mimic changes in light that would occur during the eclipse. The dates also aligned with the first clouds challenge, so there was potential to compare data between years. This challenge resulted in 23,693 cloud observations.

4) Partnering with Artemis for the NASA Moon Trees Quest

From Apollo 14 in 1971 to Artemis I in 2022, the NASA Moon Trees Program has served as inspiration in STEM engagement, education, and environmental stewardship. With the Moon Trees Initiative, GLOBE Observer embarked on a collaboration with the NASA Next Gen STEM Program, USDA Forest Service, and the Artemis Mission, with a purpose of having volunteers collect tree height observations of Apollo 14 Moon Trees and related tree species and to inspire the Artemis generation through a fun STEM engagement initiative.

Through the three-month NASA Moon Trees Quest (June 21, 2023 - September 21, 2023), GLOBE Observer Volunteers across the United States searched for Apollo 14 Moon Trees and related tree species, with the help of some guidance from the GLOBE Observer App. The Quest included five different geofence data requests corresponding to the natural range of five tree species in the United States.

When a person was close to an actual Apollo 14 Moon Tree, the app alerted you with the tree location and coordinates and suggested taking a tree height observation if safe to do so. During the three-month quest, there were 6,859 tree height observations submitted with the GLOBE Observer.

The Moon Tree Quest was significant not only because of the partnerships it established, but because it served as a pilot for geofenced data requests in the GLOBE Observer app.

5) GLOBE Observer App Development

Between 2021 and 2025, the NESEC team guided the development of several new features in the GLOBE Observer app. These include:

- A significant update to GLOBE Mosquito Habitat Mapper
- The ability to connect participation in GLOBE to SciStarter
- The development, testing, and release of a mechanism to request data collection at specified locations and times. This includes an in-app message system that can be geographically targeted.
- The integration of artificial intelligence to screen photos for appropriateness and privacy as they are submitted.
- Screen names that maintain privacy while allowing contributions to be recognized
- The implementation of the Eclipse tool in 2023 and 2024
- The addition of a special feature photo function to both Land Cover and Clouds that enables volunteers to submit non-directional photos of special events and support a broader range of science.
- In-app achievements and badges for volunteers
- An update to GLOBE Trees to include genus and species if known
- Practice Mode so volunteers can learn data collection in the app without submitting bad data

- An expansion of the Clouds satellite match system to create matches between GLOBE Land Cover and satellite data (Landsat, Sentinel 2, and Terra MODIS Land Cover Classification)

Of these, perhaps the most significant technical advancement is the geographic data request mechanism because it enables partnership with researchers and expands the potential scientific impact of GLOBE data. The data request mechanism alerts volunteers when they open the app that data are needed at or near their location. Each data request provides specific instructions for data collection as well as information about the research or community project the data will support.

This function was developed after conversations with scientists who said they would be more likely to use GLOBE data if it were collected where and when they needed it. Geofenced data requests give scientists and communities the ability to direct data collection. Anyone who has a GLOBE account may submit a data request. The application is only visible when a user is logged in to the GLOBE Observer website. The application requests information that will be visible in the app as well as information needed to review the proposed project.

The NASA Moon Trees Quest was implemented through a geofenced data request. The project served as the final pilot test for the mechanism, after which the data request tool was promoted for broader use. Significant research projects built through the data request mechanism in 2025 include:

- Snow and snowdrift photos in Delta Junction
  The University of Alaska Fairbanks, in collaboration with the NASA Snow Program, the NASA Terrestrial Hydrology Program (THP) and the Delta Junction Trails Association, submitted a request for a participatory science photo collection project from February 1 to February 28, 2025. They asked volunteers to use the GLOBE Observer app to take land cover photos of snow along the Bluff Cabin Trail in Alaska with a focus on snowdrifts.

  Snowdrifts store water and melt slower than the surrounding snowpack. Knowing where snowdrifts are can help scientists develop remote sensing techniques to find, map and estimate snowdrift water content from space.

- Wildflower Blooms
  This project asked volunteers to photograph the emergence of seasonal wildflowers in large areas and note the predominant bloom color. A NASA scientist planned to use these photos to identify blooms in satellite data. By analyzing how the blooms look in the data, scientists can then identify blooms at other places and times. The collected data was meant to help scientists look back in time through the satellite record to identify the timing and extent of blooming events and understand change.

- NASA Response Mappers
  The NASA Disasters Response Coordination System provides a variety of data products to emergency managers to help in disaster response efforts and decision making. The goal of the data request was to determine the utility of GLOBE Land Cover observations in disaster response and recovery. To accomplish this, they requested regular land cover observations during the peak hurricane season when hurricane awareness is higher. For the GLOBE data to be impactful, regular (weekly or monthly) observations of a particular location were requested over a wide geographic area.

  According to the project proposers, GLOBE observations can provide localized, timely, and geolocated photos which may help emergency managers. These photos can fill gaps in time and space that exist in satellite data and traditional information from official field reporting. First responders may use the observations to understand the extent of area impacted or support damage assessments of homes, businesses, roads, utilities, etc. Observations could help recovery personnel understand the extent of debris, or government agencies gain insight into cropland damage or document high water marks. GLOBE photos can also help verify satellite data.

- National Tree Week
  This project was the first international project. It was meant to engage GLOBE students and volunteers in measuring tree height as part of Ireland's National Tree Week. This data request was submitted to help scientists better understand the distribution and height of Irish Trees. Ireland has approximately 12 percent tree cover, this is due to centuries of clearance for intensive farming and overexploitation for timber which have reduced Ireland's once extensive woodlands to the remnants we see today.

- Blowing Snow
  Blowing snow, defined as snow lifted by wind many meters above ground, is hazardous as it significantly reduces visibility, creating dangerous conditions for both ground and air transportation. It often happens on clear, windy days over a fresh, uncrusted snowpack. GLOBE collaborators at National Oceanic and Atmospheric Administration (NOAA) requested feature photos of blowing snow to compare with satellite products that detect these events between December 2025 and March 2026.

6) Expanding Connections to NASA Satellite Data

During Science Activation 2.0, NESEC expanded the existing clouds satellite match system. As of 2025, volunteers who collect cloud data during a satellite overpass or who collect land cover data receive an email that includes their observation and the satellite data showing conditions at their location. This provides a form of feedback, helping volunteers see how their classification stacks up against classifications of the same parameters from space. Volunteers report feeling connected to NASA and appreciated through the satellite emails and the feedback they provide.

Collocated satellite data for clouds is taken at the same location within 15 minutes of the GLOBE Observer clouds observation. Collocated satellite data for land cover is the closest in time overpass of the location. This means that all land cover observations generate a satellite email, while only certain cloud observations do. In practice, clouds observations are matched to geostationary satellite data, which is "always on" for most locations, in addition to data from polar orbiting satellites, which have more limited overpasses at a location.

Emails include information about how to understand the satellite comparison with a link to a web-based table showing the collocated data. They also provide a link to updates from the GLOBE Clouds team.

Opportunities for Training and Professional Development

GLOBE Observer has always relied on in-app training to prepare volunteers to participate in data collection. We additionally provided training videos and tips, largely through social media. However, in 2022, NESEC began to consider how to expand to facilitate conversations with volunteers. Our first initiative to bring our volunteer community together for live training and support was on July 26, 2022. As part of the GLOBE Annual Meeting, we hosted a two-hour event called GLOBE Observer Connection-Conversation-Celebration (GO C3). GO C3 was structured like a conference session with three components: presentations and a panel discussion featuring volunteers, science updates, a breakout session about the future of GLOBE Observer, and a highlight of submitted observations. 115 people logged on to the event from 41 countries. 285 people registered. The event was recorded and made available on the GLOBE Observer website.

GO C3 was very successful, but it took a tremendous amount of effort. It was the sole focus of several GLOBE Observer team members for months. Holding this type of event regularly wasn't sustainable, but we wanted to offer the essence of the event routinely. We decided to try short, conversational events focused on science. Shortening the name from *GLOBE Observer Connection-Conversation-Celebration,* we called the shorter conversational events GLOBE Observer Connect.

The first GLOBE Observer Connect conversation was in April 2023. Initially, each monthly topic featured the prior month's science blog topic rotating among each of the GLOBE Observer tools. Some events brought in guest speakers, but the GLOBE Observer science leads led the initial conversations. Over time, we expanded the topics to include topics related to implementation, partnerships, and technology.

Attendance at GLOBE Observer Connect events has varied from a handful of people to just over 100. Eclipse events, technology sessions and the event that featured Civil Air Patrol have been the best attended.

Additionally, NESEC has given webinars to partners to support their implementation of GLOBE Observer. Partner groups include Civil Air Patrol, Master Naturalists, libraries, camps, Accenture, and SciStarter.

Results Disseminated

GLOBE Observer data and results are published routinely on the GLOBE Observer website (https://observer.globe.gov). Additionally, 30 peer-reviewed publications have been published based on GLOBE Observer or GLOBE Observer data since 2021. These are listed on our publications page (https://observer.globe.gov/publications).

C. Science Investigations with NASA

NESEC created and offered STEM experiences for learners and educators to engage with NASA STEM assets: science, data and subject matter experts (SMEs).

9) NASA GLOBE Clouds
10) Air Quality Student Research Campaign
11) SEES Earth System Explorers
12) GLOBE Mission Mosquito
13) Trees Around the GLOBE Student Research Campaign
14) NASA GLOBE Goes to Camp
15) ISEF Earth System Science Award
16) Libraries

1) NASA GLOBE Clouds

The NASA GLOBE Clouds team at Langley compares all possible GLOBE cloud observations that are taken within 15 minutes of coincident polar-orbiting satellite overpass or geostationary satellite images (see Tables 3 and 4). These include cloud observations submitted through the GLOBE website, GLOBE Observer app, and the retired GLOBE Email Data Entry. A data table called the satellite comparison table summarizes the person's observation as well as the satellite data and includes images of clouds taken by the spacecraft. A link to the satellite comparison table is then sent in a NASA personalized email to the observer.

Table 3. Past and current satellites used for satellite comparisons since Fiscal Year 21.

Satellites Matched with GLOBE Cloud Observations	Active or Date Matches Ended
Geostationary Satellites (Country & Agency)	
GOES-19, GOES-18 (USA, NOAA)	Active
GOES-17 (USA, NOAA)	2023-03-27
GOES-16 (USA, NOAA)	2025-4-27
HIMAWARI-9 (Japan, JMA)	Active
HIMAWARI-8 (Japan, JMA)	2022-12-22
METEOSAT-11 (Europe, EOEMS)	2023-3-21
METEOSAT-10, METEOSAT-9 (Europe, EOEMS)	Active
METEOSAT-8 (Europe, EOEMS)	2022-6-1
Polar-Orbiting Satellites	
NOAA-20	Active
Terra	Active
Aqua	December 2022
CALIPSO	August 2023

Since Fiscal Year 21, over 974k total GLOBE Cloud observations were received, with at least 86% of observations minimum matched to satellite observations per year. The team has sent out over 397k emails to GLOBE participants with their corresponding satellite image and data.

Table 4. Total number of satellite comparisons completed per fiscal year for cloud observations.

GLOBE Clouds Summary	FY21	FY22	FY23	FY24	FY25
Total Observations Received	221,289	219,105	166,194	178,009	189,306
Total Satellite Matches	227,283	248,233	189,396	191,311	189,644
Aqua	23,453	27,945	12,987	146	1
NOAA-20			21,632	27,717	26,833
Terra	22,382	27,497	17,276	17,399	5,826
GEO	181,350	192,737	137,450	146,049	156,984
CALIPSO	98	54	51	0	0
Total Emails Sent	75,575	94,282	71,227	78,878	77,272
% Corresponding to Satellites	**86%**	**91%**	**89%**	**87%**	**86%**

On July 30, 2022, the GLOBE Clouds team accomplished its *Match to a Million Milestone*, reaching one million satellite matches since the start of this work in 2017. As part of the celebration and engagement activities, NASA Langley hosted a hybrid celebration event on September 13. The event featured guest speakers by GLOBE Sponsors at NASA, NOAA, NSF, and GIO; NASA Langley Center Director and Deputy Director; the PI for CERES; an advisor with SciStarter; and several GLOBE community members pre-recorded reflections on how citizen science with GLOBE Clouds satellite matching has impacted them. Over 150 participants joined the livestream. In addition to guest speakers, the team hosted a GLOBE Clouds Poster Session with over 20 posters presented live in-person. Then, on May 24, 2024, the team reached the 1 millionth geostationary satellite match. The work to match GLOBE cloud observations to satellite data is possible with collaboration with NASA's Atmospheric Science Data Center to collocate GLOBE observations to satellites. In addition, the team also works with the Clouds and the Earth's Radiant Energy System (CERES) project, particularly the Fast Longwave and Shortwave Flux (FLASHFlux) and the Satellite ClOud and Radiation Property retrieval System (SatCORPS) teams each which develop and maintain portions of the satellite comparison process and code, for low Earth orbit and geostationary satellites respectively.

These numbers are achieved partly due to intense observation periods (IOP), or data challenges. In the last five years, the team accomplished successful data challenges (Table 5). The data challenges provided datasets to researchers and engaged the public in NASA science. All datasets are made available on the Clouds Data page.

Table 5. NASA GLOBE Clouds IOPs: 2021-2024.

Name of IOP and Dates	Details	Results
(Solar) Terminator Problem May - July 2021	The NASA SatCORPS team requested cloud observations and photographs at sunrise and sunset. The data collected was then analyzed by a NASA summer student.	SatCORPS scientist Dr. Bill Smith mentored a NASA summer intern who analyzed and compared all sunrise and sunset observations to GOES satellite data.
Cloud Challenge 2022: Clouds in a Changing Climate 15 January - 15 February 2022	Two ways to participate: (1) Make cloud observations during winter months and make them within 15 minutes of a satellite overpass. (2) Identify cloud types in photographs through the Zooniverse project CLOUD GAZE.	Received 42,703 observations with 49,455 satellite matches made. A total 321,123 photos classified in CLOUD GAZE. Videos with 3 NASA scientists and a NOAA scientist promoting the GOES-R satellite. A special video with GLOBE Student

Name of IOP and Dates	Details	Results
		Vloggers was released where they interviewed someone in their community and asked them how clouds changed over time.
GLOBE Eclipse Challenge: Clouds and Our Solar-Powered Earth 15 March - 15 April 2024	Document changes in clouds and air temperature. Collect observations days before the total solar eclipse, during the total solar eclipse, and days after to notice changes.	Videos featuring 3 NASA scientists and a blog post from a fourth scientist. Participants collected more than 23,000 GLOBE Clouds observations, which matched up with 25,444 satellite observations.

Satellite Comparisons to Land Cover Observations

In August 2025 the team expanded satellite comparison to land cover observations, sending out weekly emails to GLOBE volunteers sending in land cover photographs and reporting covering types through the GLOBE Observer app. The design of the table and code were created by two interns and supervised by our data manager Tina Rogerson (Figure 5).

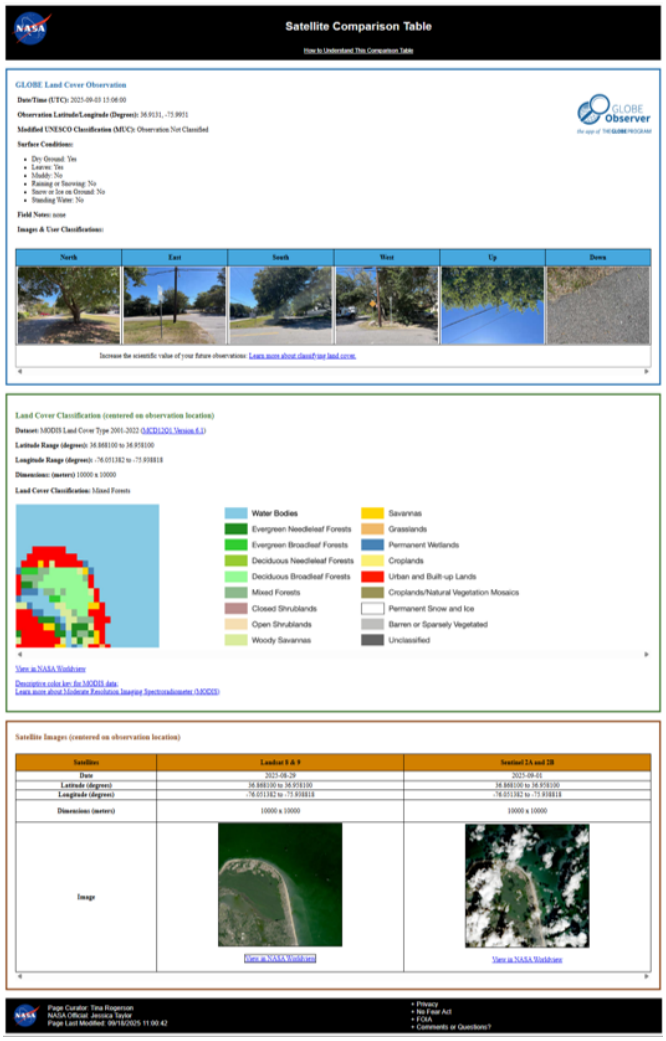


Figure 5. GLOBE Land Cover satellite comparison table.

The table is divided into three main sections. The top section summarizes the volunteer's report and includes their photographs of their site. The middle section contains the MODIS Land Cover classification site with links to see the data in Worldview and access to resources. The bottom section has images from the Sentinel and Landsat satellites centered on their location. The image chosen is based on the satellite image taken closest to the reporting date.

From August-December 2025, the team has:

- Received 4,446 Land Cover observations
- Made satellite comparisons
    - 4,388 to MODIS
    - 3,318 to Landsat
    - 3,318 to Sentinel
- Sent 1,412 emails with the new table

Multi-part Virtual Teacher Trainings

In 2023, the team tested a new framework to train teachers on how to make cloud observations using multiple hands-on activities, and how clouds are important to NASA in a four-part virtual series. A total of 20 teachers from 15 different states were trained and received classroom materials to aid in the collection of cloud observations with their students. The framework included the collection of feedback from participants after every session which was used to adjust the instructional content for the next session, and time was allotted at the start of the session to address participant's questions and comments received the week prior.

This model was then used in 2024 to run the GLOBE Eclipse five-week virtual Educator Workshop. This training was in collaboration with GLOBE Mission Earth, another Science Activation funded team. The five-week workshop was designed to prepare educators to do GLOBE student research in their classrooms by collecting observations during the total solar eclipse in April 2024. The OSU STEM Research Center conducted an evaluation of attendees' satisfaction with learning how to use the app during the workshops and the impact on attendees Earth science teaching practices. Thirty participants responded to the survey. In written comments, respondents reported that the webinars were "informative even for veteran teachers" and personnel were "knowledgeable and friendly". One respondent replied that the webinar series "helped prepare me and my students for the eclipse and I am looking forward to guiding students through the research project."

Featured Partnership with the Civil Air Patrol

The Civil Air Patrol (CAP) is a volunteer organization that serves as the official civilian auxiliary of the United States Air Force. The total solar eclipse on April 8, 2024, was a unique opportunity to design a mission for cadets, senior members, and educators to collect atmospheric data with GLOBE Eclipse. The collaboration between GLOBE Eclipse and CAP gave cadets the opportunity to do real, hands-on science and be part of a mission alongside senior members and engage in Earth sciences. Teams collected air temperature, clouds, wind, and precipitation for a total of four hours before, during, and after the eclipse. For the **first time ever**, the CAP had cadets and senior members participating in a mission from every wing (U.S. state), in addition to two U.S. territories and 2 Canadian provinces. It also brought in students and educators through the Civil Air Patrol's education sites involving K-12 formal and informal educators at schools, youth organizations, museums and libraries.

Totals from the collaboration with CAP:

- 400 teams with over 3,000 cadets and over 1,000 senior members
- Participation from every state, including two US territories and 2 Canadian provinces
- 40,000 students and more than 600 educators through the Civil Air Patrol's Aerospace Education program

Due to the success from the GLOBE Eclipse experience, CAP cadets and senior members asked for yearly missions with NASA. As a result, the 2025 Aviation Weather Mission (AWM) was designed and organized by CAP with the science task by GLOBE Clouds team based on past work with SatCORPS team and their studies of contrails and aviation weather.

The AWM mission consisted of four 4-hour observation periods from April to July 2025 where CAP members collected ground-based atmospheric observations including airport conditions, information about commercial aircraft (registration number and altitude). In addition, cadets (students ages 12-20) and senior members used the GLOBE Observer app's clouds tool to report cloud cover and contrail types. The AWM included:

- Over 3,800 mission participants
- Almost 10,000 observations collected in 48 states and 2 US territories.
- More than 1,300 commercial airplanes tracked

While participating in the AWM, CAP cadets and senior members gained valuable skills and knowledge related to collecting scientific data. After training but before collecting data, 80-100% of CAP cadets and senior members reported that they felt prepared to collect data. After participation in AWM data collection, cadets and senior members reported greatly efficacy and confidence with regard to collecting data. Specifically, over 90% of cadets and senior members agreed that they collected accurate data, followed a structured method to collect data and developed a greater understanding of the importance of data accuracy in scientific studies.

CAP cadets and senior members co-authored a poster about the AWM results and dataset at the 2025 American Geophysical Union Fall Meeting in Louisiana, USA.

Content and Resource Production

The NASA GLOBE Clouds team produces multiple content in English and Spanish following best practices in cultural relevance to better engage teachers, students, and adult audiences with clouds.

Products include:

- GLOBE Clouds Quarterly Updates (Spanish version of the latest update sent to 351 volunteers)
- Blog posts featuring bilingual activities for educators (N is for Nubes)
- Videos and data sheets for data challenges for the GLOBE Eclipse Challenge
- Updated corresponding satellite email and data table in Spanish

The GLOBE Clouds team and Queens Public Library co-developed a new GLOBE card game called NUBE (pronounced noo-beh) - the Spanish word for cloud. During this fun, interactive game, players match cards by cloud type or sky color – with 11 cloud types and 5 shades of blue (in real life, sky color can be an indication of how many aerosols are in the atmosphere). There are also special cards in the deck, such as Rainmakers, which change the order of play; Obscurations, which require the next player to draw two cards; and Mystery cards, which require players to give hints while other players guess the cloud type. By playing the game, participants practice learning the names of clouds while they begin to appreciate the differences in cloud type and sky color.

NUBE evolved through multiple iterations as staff from several Queens Public Library branches tested the game with different age groups, from young kids to teens and adults. The game was also tested at the Challenger Center and the Center for Science, Technology, Education, & Mathematics (STEM) Teaching and Learning at Northern Arizona University. In collaboration with NASA@My Library, another Science Activation team, the game was promoted into library programs around the country and distributed to more than 300 libraries.

2) Air Quality Student Research Campaign

The Air Quality Campaign focused on lending Calitoo instruments to take aerosol observations and training teachers on the use of the instrument as well as the importance of the data. In 2021 and 2022, virtual trainings were conducted to educate the educators on how air quality is

monitored from the ground to satellites. These series resulted in over 20 student air quality investigations and four GLOBE IVSS projects.

In 2023, participants of the campaign were instructed to focus on sky color and visibility in addition to aerosol optical thickness to enhance the observations and include the use of the GLOBE Observer app. Instruction was also added to monitor ground-observations from PM2.5 monitors and small sensors near the educators' locations.

The topic of wildfires became very popular as multiple groups experienced these large events, including unique observations from Standing Rock Reservation in North Dakota who had just installed their small sensor, a need in the community since closest sensors were kilometers away.

In summary, the GLOBE Air Quality U.S. Campaign reached over 40 schools, with over 30 Calitoos loaned providing one-on-one teacher support for elementary, middle, and high school students directly from the subject matter expert, Dr. Margaret Pippin.

3) SEES Earth System Explorers

Earth System Explorers (ESE) is a NESEC-led internship under the banner of the STEM Enhancement in Earth Science (SEES) managed by the University of Texas, Austin, Center for Space Research. This collaboration between two SciAct awards (NESEC and SEES) leveraged NASA's investment and each project's unique capabilities, making greater impacts than would be possible working independently. From 2021 to 2025, NESEC supported the participation of 349 high school interns in robust, NASA-SME-mentored summer research, and engaged an additional 45 peer mentors, who returned a second year to participate in the internship. This research resulted in 79 GLOBE International Virtual Science Symposium submissions, and 72 AGU Bright STaRS high school research poster presentations.

The core ESE mentor team includes Dr. Rusty Low (mentor team lead), Cassie Soeffing, and Andrew Clark, IGES; Peder Nelson, OSU, and Dr. Erika Podest, JPL.

History of SEES ESE

The virtual high school research internship began in 2018 as a collaboration with UT-Austin's Science Activation team, providing a NASA science opportunity for students who could not be accommodated by the limited spots available in the SEES program (only 50 slots available with >600 applicants). Most of the applicants who were turned away were deemed highly competitive. Originally named "Mosquito Mappers," this opportunity aimed to reduce disappointment in these motivated students, but it simultaneously supported NESEC's goal to amplify data collection using the GLOBE Observer Mosquito Habitat Mapper tool. What began as an informal enrichment experience for students who could not participate in SEES evolved to become the first official SEES *virtual* internship in 2020. During Science Activation 2.0, the virtual internship was offered by NESEC each summer during the period of performance 2021-2025 to include between 50 and 100 rising high school juniors and seniors.

Over the five years, the mentor team made iterative modifications to the core program in response to rapid changes taking place both in technology and in science that made it possible to host a team science research internship in a remote setting. These changes included the availability of NASA's GLOBE Observer citizen science data collection tool, which leveraged the GLOBE Program database and infrastructure and allowed participants to coordinate their research and collect, view, and share data with each other (Amos, et al., 2020). During the past decade, studies demonstrating that thoughtfully structured citizen science projects can achieve data standards comparable to those of professionals have markedly enhanced scientists' confidence in the quality of such contributions (Downs, et al., 2021). Emerging technologies, including data access tools, mobile apps, and cloud-based platforms, such as ArcGIS Online, open participation to broader audiences by empowering contributors to handle complex data analyses independently (Newman, et al., 2012; Strassler, et al., 2023).

SEES ESE: Focus and Evolution

The focus of the SEES Earth System Explorers internship is to provide emerging scientists the opportunity to examine and analyze NASA Earth data obtained through remote sensors on satellites, hand-held portable sensors, and ground-collected citizen science data. Interns were introduced to research actions associated with each phase of the data cycle, beginning with data collection- a step missed in many research internships. The data collection experience assists in understanding the nature of scientific data, including the importance of understanding the fitness of use of a data set with reference to a specific research question they have identified and the quantity, geographic scale, potential for inaccuracies, human error, and data quality.

GLOBE Observer was a critical part of our ability to offer a virtual internship experience, connecting students directly to a NASA data experience. The mobile app enabled interns to collect local data relevant to their own community, providing an opportunity for the program to deliver a place-based research science experience for each student.

In 2020, the internship shifted its focus from the collection and analysis of data obtained using the Mosquito Habitat Mapper tool (Mosquito Mappers) to the Land Cover tool on the GLOBE Observer platform (Earth System Explorers). The reason for this shift was to provide a more robust research experience for the interns and was related to inherent challenges in the collection of mosquito data. Because mosquitoes are not evenly distributed across the landscape, obtaining large enough samples for research projects can be challenging. In addition, opportunistic data collection, defined as gathering data without a predefined protocol or systematic sampling design, creates challenges that limit reliable scientific inference. These include the application of standard statistical tools that make assumptions about potential bias in a sample that are not met when data are collected opportunistically.

To avoid the potential limitations in analysis, we developed a land cover sampling design strategy for use with the GLOBE Observer data collection: Adopt-a-Pixel 3km (Low, et al., 2021). By aligning the focus of research with land cover, we created more opportunities for the interns to compare their ground-based citizen science land cover observations with remotely sensed

data sets and other NASA data. We were also able to leverage and include SMEs funded through a NASA EPSCoR solicitation, who applied computer vision techniques to citizen science data to automate land cover classification (Huang, et al., 2023; He, et al., 2025; Yang, et al., 2025). In addition, AppEEARS (Application for Extracting and Exploring Analysis Ready Samples), a NASA-developed platform for satellite data access and processing became fully operational in 2019, simplifying the extraction of NASA MODIS, VIIRS, and Landsat data products to personal machines without GIS labs. The research design we proposed for the interns embraced the paradigm shift emerging in land cover science and described in the article "Land Cover 2.0" by Wulder, et al., (2018), moving the science to a cloud-native land cover product production.

A significant concern in the development of a virtual internship was the lack of examples of virtual internships in the literature that we could use as models. COVID-19 catalyzed a global pivot to online education during the lockdown, beginning in March 2020. It also triggered a massive surge in research on online learning practices and outcomes, with thousands of peer-reviewed studies published from 2020 through 2025. These studies evidenced some of the real challenges associated with the transfer of classroom experiences to digital platforms. A study by Berens and Hobert (2025) indicated that students tested with higher learning success in this new situation compared to the traditional learning process. However, they raised concern about student isolation and suggested the pandemic to be "a natural experiment" that helped to "identify possible risks in remote learning, such as stress or loneliness." Theirs and other analyses underscore the importance of fostering emotional health in online learners as part of e-learning instructional design.

The SEES internship in 2020 was conducted during the pandemic and made us acutely aware of the need to create an inclusive, supportive, and highly interactive digital environment to support student collaboration and teamwork. Many of the design decisions of the Earth System Explorers internship were in response to how the 2020 cohort interacted halfheartedly with the Learning Management System (Canvas) and created their own networks of communication using social media tools such as Discourse, which they found more engaging. The most successful component of the internship was a biweekly virtual lab experience we called "Meet up and do science." This was intended to be the virtual equivalent of sitting next to a colleague in a research lab, where informal discussions can take place, promoting mutual understanding and positive science outcomes.

Between 2021 and 2025, iterative improvements were made to the internship (Table 6).

Table 6. Earth System Explorers internship innovations and rationale, as informed by pedagogic theory.

Year	Innovation	Reason	Supporting Pedagogic Theory/Research Approach
2018	**Mosquito Mappers** **Virtual citizen science team webinar series**	Provides a participatory science opportunity collecting NASA data for students for which there were no internship slots Leverages new citizen science project, enabling distributed participation (GLOBE Observer)	● Place-based learning (Semken, et al., 2017) ● Action research (Crawford, 2022) ● Self-Determination Theory (Chiu, 2023; Wang, et al., 2024)
2019	**Employ learning management system (LMS)**	Formalizing project into an independent research experience under scientist mentorship, using citizen science data	Student-centered instruction (Pem, et al, 2021)
2020	**Earth System Explorers** **Meet up and Do Science**	ESE becomes official SEES Internship and first virtual internship Mandatory synchronous meetings to support strong team engagement	Sense of Belonging Theory (Strayhorn, 2012)
	Adopt a Pixel	GLOBE Observer Land Cover citizen science tool released. Use of shared land cover sampling methodology enables application of statistical techniques to data	● Research Design (Wulder, et al., 2018) ● General Internship model Bell, et al., (2010) ● Data literacy (Dogucu, et al., 2025)
	Cloud-based data access & analysis tools	Sampling design enables meaningful articulation to remote sensing data and analysis tools	Research Design (Wulder, et al., 2018)
	Meet A Scientist	Program component required of NASA SciAct projects	Science Capital theory (Archer et al, 2015)
	AGU presentations	Enabled through recognition as an official SEES team	Science Capital theory (Archer et al, 2015)
2021	**Peer mentors**	Provide additional support for interns + interest expressed by interns to continue work	Sense of Belonging Theory (Strayhorn, 2012)
2022	**Team Science Leadership Module**	SEES intern stimulated the idea and volunteered to contribute to creation of a team science module	Science of Team Science theory (NAS, 2015)
	Digital community platform	New digital research lab platform maximizes ability to interact and build team connections (Mighty Networks)	Blending with Pedagogic Purpose Model (Picciano, 2017)
2023	**Open Science module**	Supports NASA Transform to Open Science initiative, GitHub/Zenodo data	Open data paradigm shift (Gong, et al., 2022)
2024	**Community Chronicles**	Public science communication, technological literacy (ArcGIS StoryMaps)	Place-based learning (Semken, et al., 2017)
	Professional science identity	ORCID number, headshots, poster talk videos	Science Capital theory (Archer, et al., 2015)

Innovations to meet interns' needs

Literature reviews identified how science research internships develop many different facets of emerging new researchers, and we realized that these nuanced benefits of internships that can occur organically in face-to-face environments needed to be built into the program with intention. A SEES intern stimulated the idea of offering a Team Science module, and offered to co-develop the content, drawing from a teen leadership course she took at school. This intern returned the following year as a peer mentor in 2022 to lead some of the team science activities.

In 2022, we identified what we believed would be a compelling alternative to using an LMS for internship delivery. Mighty Networks is an all-in-one *"community-first"* platform that lets creators, educators, and organizations host an online community, courses, events, and memberships in one place. It is designed so participants can effortlessly interact with each other. Far more flexible and inviting than LMS environments used in school settings, Mighty Network became our research internship platform. It supports not only events and live interaction through an integrated Zoom platform, but it also enables live chats between participants, as well as direct messaging (DMs), threaded discussions, team spaces, and blog posts. All assets needed by the internship can be linked to participants through the platform. The platform provided a social media-like experience between the interns, which also allowed mentors to monitor online interactions and provide a safe digital environment for intern engagement.

Another innovation was the creation of an open science module. 2023 was designated by NASA as the "Year of Open Science" to emphasize the importance and advantages of open science principles in driving innovation. As part of this, the SEES ESE internship introduced interns to open science principles and their applicability in Earth science research. The shift to open science is a fundamental change in how research science is understood, approached, and conducted. As scientists, we are responsible for engaging our students and emerging scientists in the ethos and practices of open science and open data. To meet this need, we developed an instructional framework to introduce summer high school research to the open science ecosystem and the data-sharing practices central to open data and open science. The open science modules scaffold open science and open data practices as part of their first research experience. Along with presenting their final projects at the SEES Science Symposium in August, individuals are responsible for establishing their ORCID account. Teams are expected to share data sets and code products they created for use in their analysis using Zenodo or GitHub.

Through these and other experiences, Earth System Explorers explicitly supports interns in developing science capital. Science capital refers to the science-related knowledge, behaviors, attitudes, and social contacts students accumulate (Archer, et al., 2017). Exiting the Earth System Explorers experience, interns have not only conducted an original research project using NASA data and science assets and presented at a scientific meeting, they have also had experience working with data across the data life cycle (from field data collection to archiving), and built science-related social capital by meeting and discussing science with the NASA SMEs who present during the internship, their internship mentors and peer mentors and their peers.

By asking for project metadata in an ArcGIS StoryMap format “Community Chronicles”, they leave the internship prepared to present their science at their school or library, and we foster their science identity through contributions to their community.

In 2025, we added an additional innovation to the suite of internship experiences: “Meet up and write science.” Interns were given the option of working with mentors on a manuscript this winter, which will be submitted to the Journal of Earth Observations and Geospatial Applications in February 2026.

In 2025, more than 2,100 students applied to SEES, and 174 (8%) students were accepted into the program. The virtual option enabled more students to participate, because the cost per student is much lower than the face-to-face option. Of the 174 interns, 82 were selected for the on-site program, 92 joined virtual teams, and 49 of the virtual interns participated as Earth Systems Explorers.

Since 2019, 520 rising junior and senior high school students have completed the Earth System Explorers research internship. Each intern conducted 120 to 150 hours of research, working closely with NASA SME mentors and peer mentors who participated in a previous year. The internship takes place over two months, each intern spending approximately 15 hours per week. This schedule provided the flexibility many interns needed to accommodate summer jobs and family responsibilities. Participants experienced fieldwork, examined remotely sensed satellite data, and completed a team research project contributing to the scientific understanding of mosquito ecology, human health, and land cover classification. Interns accessed and analyzed data using online tools such as the GLOBE Advanced Data Access Tool, Collect Earth Online, AppEEARS, NASA Worldview, Climate Engine, Google Earth Engine, and ArcGIS Online. Students also had the option of completing up to three Python coding modules from the University of Texas.

Data Products and Research Outcomes

Data products and research outcomes resulting from the 2021-2025 SEES Earth System Explorers teams include 1) a co-authored peer-reviewed research paper (Low, et al, 2021), 2) student research projects submitted to the GLOBE International Virtual Science Symposium (IVSS) 2021-2025, and 3) Individual and team projects submitted to the 2021 Fall AGU Meeting high school student poster session, Bright STaRS (2021-2025). In addition, three presentations were submitted to the general AGU poster session by the six 2021 SEES peer mentors, who became undergraduates in 2021 and were not eligible to participate in AGU’s Bright STaRS. Several of the 2025 SEES ESE cohort are now working on a research paper that will be submitted to the Journal of Earth Observations and Geospatial Applications in February 2026.

What began as a month-long informal summer NASA citizen science opportunity for high school students who were not selected as SEES interns in 2018 has evolved into a robust science research internship connecting citizen science and remote sensing. We see the Earth System Explorers research internship structure and design as a persistent outcome of NESEC’s work. An

article describing the Earth System Explorers virtual interns as a replicable model to expand science enhancement experiences for youth is currently underway by the SEES ESE team.

Internship Outcomes

Following are some examples of internship outcomes by year. These are in addition to each intern completing a research project that uses NASA data and science assets, and presenting their research in the SEES Science Symposium, the AGU Bright STaRS poster session (live or virtual), and submitting their project to GLOBE's International Virtual Science Symposium. In addition, over the period of performance, 132 blogs were written by interns and uploaded to the GLOBE Mission Mosquito website.

2020: Students participated in the development of the Adopt a Pixel 3km fieldwork research design used for sampling land cover data. They contributed to the creation of an article published in a peer-reviewed journal (Low, et al., 2021).

2022: A focus began on science communication and continued through 2025. In 2022, Sixty-five interns completed optional blogs describing their mosquito trapping experiments. Student blogs (and beginning in 2024 ArcGis Story Maps) were released regularly on the GLOBE Mission Mosquito (GMM) website to stimulate GLOBE International Virtual Science Symposium (IVSS) project ideas for teachers and students.

2023: A focus on science capital: Science Teamwork and Leadership is a module designed to introduce interns to features of science culture that they may not have experienced. The module provided activities that engaged students in discussions about equity, inclusion, bullying, authorship and acknowledgments, science ethics, and collaboration. Data Ethics for Practitioners is a module created by SciStarter and leveraged for SEES ESE in 2023 to support interns to "think like an ethicist" by identifying relevant ethical obligations, tensions, and issues. During summer 2023, 45 interns completed blogs describing their mosquito trapping experiments.

2024: Moved from allowing free selection of research topics to guided individual research collecting local land cover data and comparing with data collected by other interns to identify research questions.

During the summer 2024, interns were assigned to create an ArcGIS Community Chronicle StoryMap. The Community Chronicle provides a contextual and historical envelope to better understand land cover features observed in their research. It serves a dual purpose: to provide explanatory metadata about their study site, and to connect their quantitative research project to concrete and compelling messaging they can share with fellow students at school and community members.

2025: This year, the teams all shared the same research methodology in preparing descriptions of their study site and comparing their ground-based observations to selected map products derived from remote sensing data. The shared methodology used to answer very different

environmental questions by the Earth System Explorer teams enabled the creation of a cohesive manuscript using research products by the individual interns. Interns were given the option to collaborate one hour a week in the winter and "Meet up and write science." About 20% of the interns have participated in these sessions, plans are to submit this manuscript to a new journal, *Journal of Earth Observations and Geospatial Applications,* which has solicited short case study articles for submission in February 2025.

From 2019-2025, there were numerous success stories for individual interns, including an AGU Outstanding Student Presentation Award (competing with college-level students), five Regeneron Competition Finalists (Science Talent Search and International Science and Engineering Fair), and prestigious scholarship awards (e.g., Morehead-Cain Scholarship), and numerous other recognitions (e.g., national and regional competitions and media stories).

In January 2026, a former SEES ESE intern and peer mentor, Matteo Kimura, was named as one of *Forbes 2026 "30 under 30 for Science."* In 2024, he described his SEES experience in a letter in support of the SciAct AGU award for Excellence in Earth and Space Science Education: *Despite being a high school student, I was treated as a collaborator…This respectful environment not only boosted my confidence but also significantly enhanced the quality of my contributions… These experiences have had a lasting impact on my academic and professional journey as a sophomore at Caltech. The open science approach instilled in me a collaborative spirit that helped me facilitate a collaboration between a Caltech student group and a JPL research project on a $3 million proposal."*

4) GLOBE Mission Mosquito

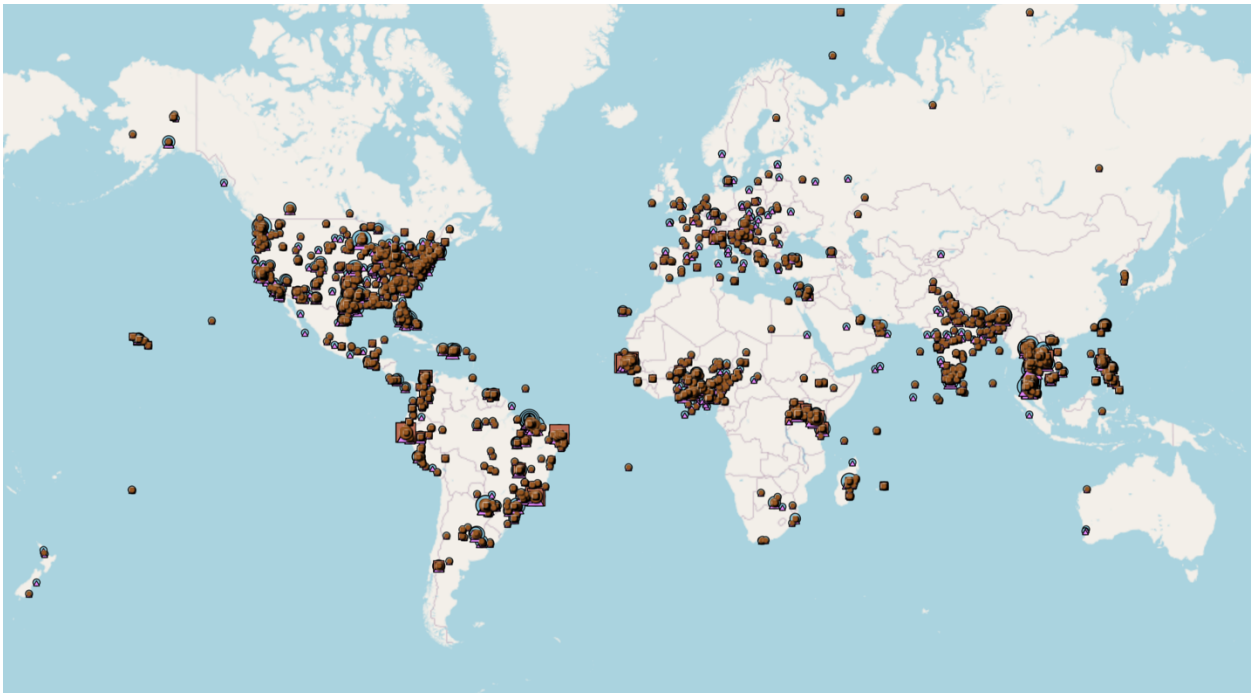
GLOBE Mission Mosquito (GMM) was an international field campaign supporting citizen scientists of all ages to monitor changes in the frequency, range, and distribution of potential disease vector mosquitoes by reporting observations using the GLOBE Observer Mosquito Habitat Mapper. These data can be downloaded from the GLOBE database and analyzed to explore a variety of research questions. The human health connection of GMM engages a broader audience by providing opportunities for citizen scientists interested in health and environmental equity. By leveraging these interests, the campaign offers a point of entry for individuals who are unfamiliar with Earth science and engages them in learning more about NASA Earth observations and the role of the dynamic Earth system in human health.

Cassie Soeffing (IGES), GMM Campaign Coordinator, and Dr. Russanne Low (IGES), GLOBE Mosquito Habitat Mapper Science Lead, led the campaign. Education and outreach specialists Liz Burck (IGES) and Dorian Janney (GSFC/ADNET) contributed significantly to GMM outcomes, particularly in the development of educational resources and as webinar hosts. In 2021, GMM established an international advisory group to ensure the campaign responded to U.S. and global educational needs and challenges that participation in GMM citizen science can address. The advisory group included members of the GLOBE Program: Dr. Michael Jabot, U.S. GLOBE Partner and university professor; Juan Filipe Restrepo, GLOBE Master Trainer for Latin America and the Caribbean, Colombia; and Inês Mauad, GLOBE Brazil Observer Mosquito Habitat Mapper educator and trainer. Anita Schiller, Director of the Biocontrol Mosquito Initiative in Harris County, TX, Precinct 4 joined the advisors as a mosquito ecologist and vector control specialist. Dr. Carole Mandryk, the Director of the Osher Lifelong Learning Program at the University of Hawaii, Manoa, also supported our development of targeted outreach strategies to engage senior audiences. Through the guidance and support of this group of advisors, the GMM team identified webinar topics and valuable resources to develop. These individuals also contributed content, supported outreach through their own networks, and added to the reach and impact of the GMM team.

The GLOBE Mission Mosquito campaign started during SciAct 1.0 and remained an official GLOBE Program campaign from 2021-2025. During this time, GLOBE Mission Mosquito received national and international recognition for its contributions to global health. Global estimates suggest that mosquito-borne diseases together are responsible for one million deaths worldwide (Piovezan-Borges, et al. 2022), with malaria accounting for most of these deaths (WHO, 2025). These are approximate numbers because surveillance and attribution vary widely across countries and diseases.

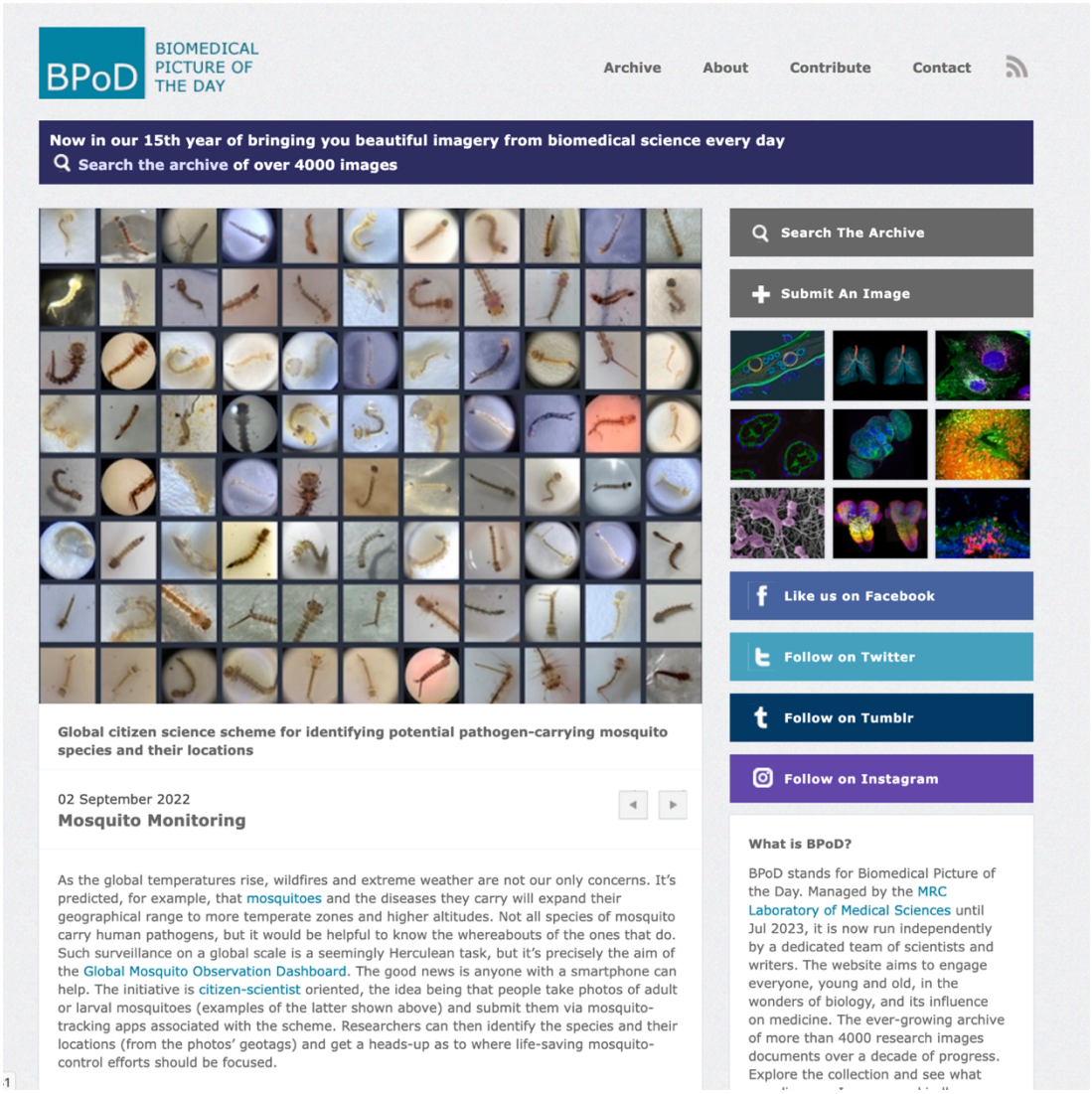
Connecting mosquito research to local disease threats fosters a sense of agency among citizen scientists, as participants see direct links to protecting their families and neighbors from endemic illnesses (Roja et al., 2022). As a result, there was strong community-based interest, leading to frequent requests for webinars, workshops, and training sessions, as well as data collection in 84 countries (Figure 6). The citizen science program has also generated significant attention, not

Figure 6. Screen capture, GLOBE Visualization System, Mosquito Habitat Mapper Observations, 05/30/2017 to 01/10/2026, there were 93,224 data points reported. Data downloaded January 10, 2026, https://vis.globe.gov/GLOBE/.



only among the expected education and outreach audiences, but also institutions and agencies that understand the critical importance of public engagement in mosquito surveillance and breeding site mitigation. Photos of larvae submitted by citizen scientists during the 2021 GLOBE Mission Mosquito campaign were highlighted by the MRC Laboratory of Medical Sciences, London, as the Biomedical Picture of the Day (Figure 7).

Figure 7. Screenshot, Biomedical Picture of the Day, September 2, 2022. Available at https://bpod.org.uk/archive/2022/9/2.



In another example, the Wilson Center hosted an expert roundtable, in partnership with Malaria No More and the U.S. President's Malaria Initiative, including a member of the science team for GLOBE Observer Mosquito Habitat Mapper, Dr. Rusty Low (Sihna-Chaudhuri and Parker, 2024). The U.S. State Department invited the GLOBE Observer Mosquito Habitat Mapper team to present as part of the Foreign Institute's Global Health Diplomacy Course (2024-2025), In fall 2024, the U.S. Department of State Speaker Program sponsored a lecture tour by Dr. Low to discuss how the Mosquito Habitat Mapper supports public surveillance and mitigation of mosquitoes during the historic dengue pandemic that year in Central America and the Caribbean (PAHO, 2024).

Science Research Collaborations and Outcomes

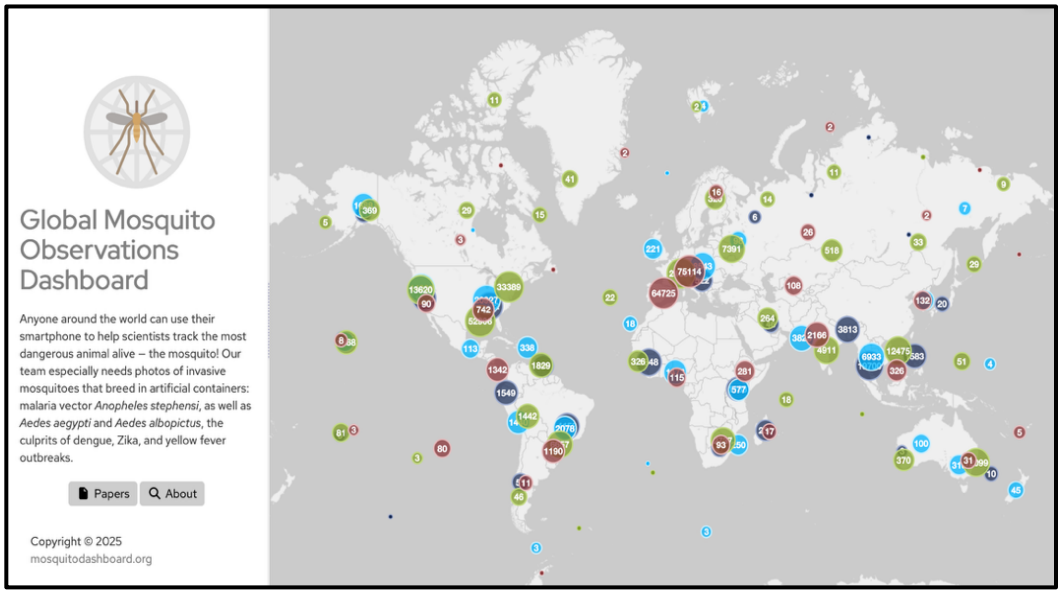
GMM collaborated with the following science teams:

- NSF Mosquito AI Project: The University of South Florida leads this project, which uses GLOBE MHM data to develop AI for larval identification from citizen-science photos. Dr. Low was Co-PI of this NSF project, which included Co-Is from the Wilson Center and the Centers for Disease Control (CDC). This research resulted in five peer-reviewed publications and stimulated the development of the Global Mosquito Dashboard. The dashboard displays data from three mosquito citizen science programs: GLOBE Observer Mosquito Habitat Mapper, Mosquito Alert, and iNaturalist (Figure 8). It also displays GLOBE Observer Land Cover data. Importantly, two NESEC-sponsored high school research interns from the STEM Enhancement in Earth Science (SEES) program were embedded in this project with IGES after their SEES summer internship and created the code that enabled GLOBE Observer data to be interoperable with the other citizen science datasets. The U.S. Department of State initially supported the project, which the University of Wisconsin–Madison now houses.

- EPSCoR: Four NASA science teams from EPSCoR states used the citizen science data to automate photo classifications of mosquito habitats, mosquito larvae taxa, and land cover. The NASA EPSCoR grants ran from 2021-2023 at New Mexico State University, the University of Puerto Rico, San Juan, the University of Vermont, Burlington, and the University of Wyoming. Of the four teams, only one (Di Yang, University of Wyoming) examined Mosquito Habitat Mapper data as part of their research; the other teams focused their research on Land Cover classification. Yang's work served as the seed for a NASA ROSES research project.

- NASA ROSES project, Forecasting Mosquito-Borne Disease Risk in a Changing Climate: Integrating GLOBE Citizen Science and NASA Earth Modeling (Yang, D., PI, 2025-2028): Low is a named collaborator on this project.

Figure 8. Screenshot of the Global Mosquito Observations Dashboard.
Downloaded January 10, 2026, from https://mosquitodashboard.org.



Participants in GMM included educators and learners of all ages, both in-school and out-of-school, who used the GLOBE Mosquito Habitat Mapper tool to report their mosquito habitat and larva observations to the GLOBE database. Container-breeding mosquitoes reproduce in standing water, often found in artificial containers such as buckets, gutters, plant saucers, and discarded tires. In 2021, the campaign took advantage of the release of the GLOBE Observer Land Cover tool and requested that citizen scientist contributors submit coincident (same place, same time) land cover observations along with their mosquito habitat observations. GMM promotes the value of simultaneously making GLOBE Land Cover observations to contextualize mosquito habitats and enhance the overall scientific value of the collected data. Lorenz et al. (2020) highlight that this combined data is crucial for improving predictive models based on satellite imagery, which provided a segue to a deeper dive into GLOBE data through webinars focused on open science and data.

Unlike other tools on the GLOBE Observer Platform, the Mosquito Habitat Mapper does not have a direct link to specific NASA remote sensing products. Scientists who develop risk models to describe and predict outbreaks of vector-borne disease routinely employ remote sensing data. The citizen science data collected through GMM provided proof of concept that ground-based citizen science observations (mosquito habitat and land cover data) could be a valuable component for downscaling predictive disease models. GLOBE Mission Mosquito supported citizen science training and educational resources for participants in the NASA ROSES project, Forecasting Mosquito-Borne Disease Risk in a Changing Climate: Integrating GLOBE Citizen Science and NASA Earth Modeling (Yang, D., PI).

The scientific parameters established by the research projects alluded to above played a significant role in the content shared in GLOBE Mission Mosquito webinars and in education

and outreach products. Citizen scientists who interact with GLOBE Mission Mosquito show strong interest in supporting and contributing to NASA science (Amos et al., 2020), and outreach activities prominently showcased research in progress and its outcomes. The authentic assessment of the work conducted by the GLOBE Mission Mosquito team is the number of peer-reviewed publications that resulted from their work. Ten publications resulted from this project, including five that included NASA high school interns as authors (see Appendix A).

Outreach Activities and Outcomes

GMM engaged participants through a dynamic monthly webinar series. More than 2,800 educators, scientists, and citizen scientists attended 85 webinars over the course of the campaign. The series connected the public to GLOBE Observer Mosquito Habitat Mapper through a program that included informational webinars (how-to), current events (mosquitoes in the news), research in progress (featuring NASA SMEs and research collaborators), and presentations by community members highlighting their work. The community members frequently included students, including GLOBE students who conducted mosquito research for their GLOBE International Virtual Science Symposium submissions, as well as NASA SEES high school interns.

Social media products included a series of blogs posted on the GLOBE Mission Mosquito website. Ninety-nine blogs were published during the period of performance, most of which were written by NASA SEES student research interns. In addition, the GMM team coordinated five blogs and presentations for the GO Connect series.

During 2021 to 2025, the NESEC team maintained an active and engaging outreach program. In addition to reaching out to citizen scientists directly through the GLOBE Mission Mosquito webinar series (48 webinars), the team was responsive to requests to share NASA science with interested federal and international entities (22 presentations). The GLOBE community demonstrated significant interest in mosquito research - the team was invited to share science through virtual and face-to-face workshops: (23 workshops), and other workshops (44). The team also regularly presented at scientific conferences (27 presentations), establishing community partners and productive collaborations. **Totaling 164 presentations, workshops, and webinars** led by the GLOBE Mission Mosquito team.

GMM developed numerous educational resources tailored to different learning styles and interests. These are all available on the campaign website.

5) Trees Around the GLOBE Student Research Campaign

The Trees Around the GLOBE Student Research Campaign commenced on September 15, 2018, aligning to the launch of NASA Ice, Cloud, and land Elevation Satellite-2 or ICESat-2 Satellite, which is currently in space measuring Earth's tree and vegetation height as one of its primary science objectives. With the combination of NASA missions, both space and airborne including ICESat-2, GEDI, ECOSTRESS, Landsat, GRACE, Delta-X, SWOT, PACE, NISAR, and others, the

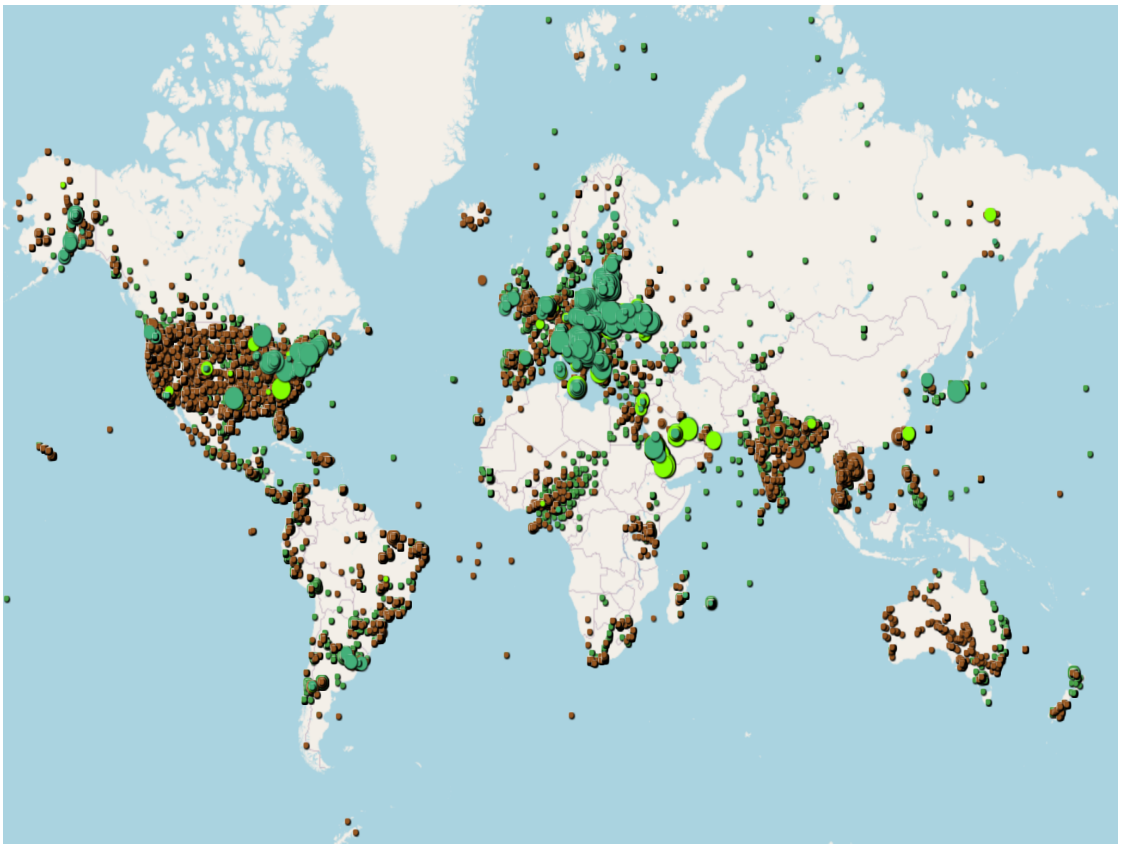
campaign focuses on aligning GLOBE Program student research to ground-based and space-based tree height, land cover, greenness (can be aligned to GLOBE Greenings – Green-Up/Green Down), and carbon cycle research. GLOBE students, educators, and citizen scientists have been taking tens of thousands of ground-based observations each year through GLOBE Program and GLOBE Observer measurement and observation protocols, and the campaign serves as a major conduit to bringing all these observations together. The campaign has active participants from 70 GLOBE Program countries (see Figure 9).

Campaign Team Members included Brian Campbell, Lead, (NASA Wallops Flight Facility/GST, Inc), Peder Nelson (Oregon State University), Peter Falcon (NASA Jet Propulsion Laboratory), Dorian Janney (NASA Goddard Space Flight Center/ADNET), and Dr. Christopher Shuman (NASA Goddard Space Flight Center/UMBC).

Figure 9. Map showing locations of active countries (70) for the Trees Around the GLOBE Student Research Campaign.

Over the life of the campaign, there have been >270,000 observations (see Figure 10) of tree height, land cover, and greenings (green-up in spring and green-down and fall), from >85,000 locations in >100 GLOBE countries. During the last 8 years, there have been 125 webinars (with >12,000 participants at the live event), 83 blogs (with >400,000 views), and events that introduced learners to NASA science and >100 subject matter experts (SMEs) that brought the relevant science and technology directly to the campaign participants.

Figure 10. Data map showing the locations of tree height (dark green), land cover (brown), and greenings (bright green) for the life of the Trees Around the GLOBE Student Research Campaign (September 15, 2018 – December 31, 2025).



The campaign team has created 20 online tutorials for investigating and comparing GLOBE and NASA satellite data using online tools (e.g., Open Altimetry, Collect Earth, MY NASA Data, Google Earth Engine, and ArcGIS Story Maps), which played a major role in the submission of >150 campaign-related research projects to the International GLOBE Virtual Science Symposium (IVSS) over the last eight years (see Figure 11). As part of Year 3 of the campaign, the campaign team designed and implemented a half-day virtual workshop where students from all six GLOBE Program regions presented their campaign-related IVSS projects. Throughout the eight years of the campaign students have presented over 150 student projects at campaign webinars from over 50 GLOBE countries.

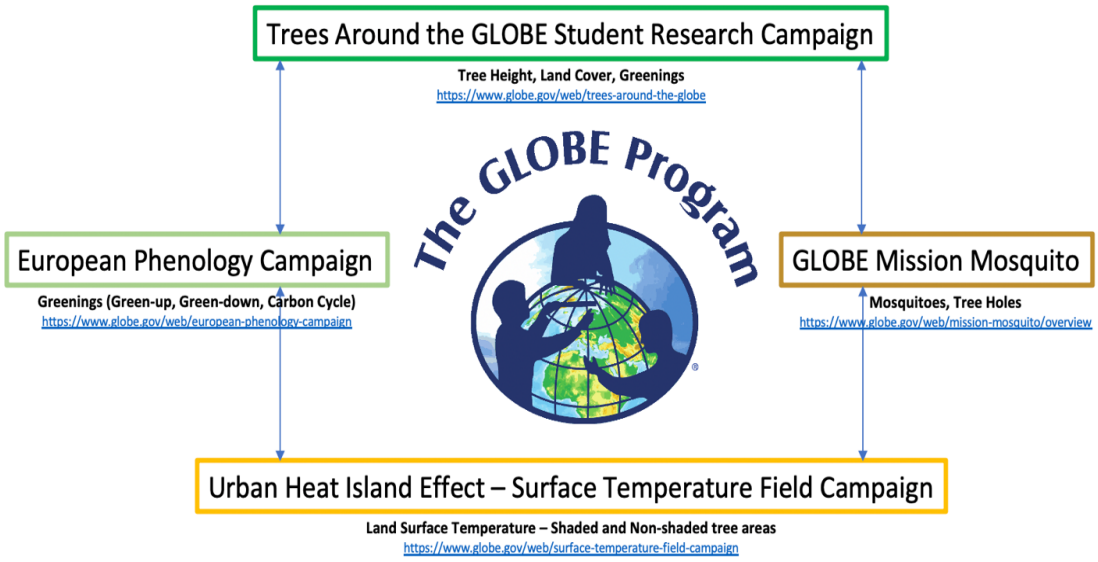
Figure 11. Examples of Trees Around the GLOBE Student Research Campaign-related IVSS projects submitted over the last eight years focusing on tree height and land cover research.

One of the major components of the Trees Around the GLOBE Student Research Campaign are its alignment to, and creation of, campaign-related data collection Intensive Observation Periods (IOPs) for tree height and land cover. Examples of these include:

- 2020 One-Week Land Cover IOP
- 2021 Community Trees Challenge
- Spring 2022 Tree Height and Land Cover IOP
- Summer 2023 NASA Moon Trees Quest
- 2025 Search for Tabebuia Trees with GLOBE Observer Land Cover and Trees Tools
- 2025 GLOBE Africa Tree Measurement IOP

Over the life of the campaign, there have been many collaborations, including those with the USDA Forest Service, the Himalayan Reforestation Project (India), the Keystone 10 Million Trees Partnership (Pennsylvania), International Forest Conference (Slovenia), and several NASA missions like ICESat-2, GEDI, Landsat, GPM, SMAP, and others. Collaborations with other GLOBE Campaigns were a highlight of the Trees Around the GLOBE Student Research Campaign. The focus was to leverage data and data analysis for data literacy with GLOBE Mission Mosquito, Urban Heat Island Effect – Surface Temperature Field Campaign (now known as the Urban Heat Island Effect Surface Temperature Intensive Observation Period), and the European Phenology Campaign (see Figure 12).

Figure 12. Graphic showing the interconnectedness of the Trees Around the GLOBE Student Research Campaign with GLOBE Mission Mosquito, European Phenology Campaign, and the Urban Heat Island Effect – Surface Temperature Field Campaign (now known as the Urban Heat Island Effect Surface Temperature Intensive Observation Period).



6) NASA GLOBE Goes to Camp

The idea for the GLOBE Goes to Camp project began in 2018 with the vision of establishing a network of NASA GLOBE camps across the United States that were actively engaged in the collection of environmental data. Throughout the fall of 2018, aspects of GLOBE implementation in informal education settings were reviewed, and resources were developed to support a pilot of GLOBE Goes to Camp beginning in 2019 with the GLOBE cloud protocol.

In February of 2019, GLOBE Goes to Camp Project Lead, Tina Harte Ballinger, attended the American Camp Association's National Conference in Nashville, Tennessee sharing the opportunity to become a NASA GLOBE Camp with camp professionals from across the United States. Following the conference, three camps from the states of Indiana, South Carolina, and Virginia joined the pilot, each incorporating the GLOBE Clouds protocol and learning activities with their summer campers. During the fall, feedback was gathered from each of the camps to gain insight to help direct changes for the following year. From the feedback it became apparent that ease of implementation of the GLOBE camp resources was impacted by whether the camp was in a rural or urban area. Steps were taken to address this in preparation for summer of 2020 by **providing additional modifications for those collecting data within an urban area with limited access to outdoor observation areas.**

In 2020 with the crippling restrictions of the pandemic, Camp Discovery in Blythewood, South Carolina was the only camp to continue with implementation. They initiated a GLOBE family camp experience incorporating separate stations for families to be able to participate in GLOBE activities while remaining at a safe distance from each other. Families had the opportunity to collect surface temperature data and make cloud observations during their visit to Camp Discovery, a welcome relief from the effects of the isolation associated with the pandemic. From lessons learned during the pandemic, a virtual camp learning guide for clouds and surface temperature was developed in partnership with an education intern and piloted by Tech Trek in the summer of 2021 and 2022. It was found to be a positive option for camps that were unable to return to in-person; however, it lacked the team building experience reported to be such a positive component of the project by those participating in-person.

For some, in-person camps were able to resume during the summer of 2021, resulting in eleven camps from across the United States participating in the GLOBE Camp 2021 summer pilot. Over 45 camp directors, staff and facilitators participated in one of six virtual GLOBE protocol trainings that were provided to ensure proper data collection techniques. Monthly meetings with the camp directors provided the opportunity to share lessons learned, ask questions, and begin to develop a network of GLOBE Camps. Through a series of **NASA subject matter expert (SME) connections, campers were able to interact with NASA scientists**, learn about their various missions, share the data they were collecting, and learn from other campers. The excitement was evident as the campers recognized the fact that they were connecting with and contributing to NASA and the GLOBE community. The satellite match emails brought a sense of authentication and excitement to the camps' efforts, as a "cool" factor that campers were able to share with their families. Across the 11 summer camps, over 2,000 campers engaged in authentic NASA GLOBE data collection.

In the fall of 2021 Shady Creek Outdoor School in Nevada City, CA joined the pilot, implementing GLOBE classes as a component of their outdoor school camp experience. They hosted 5th and 6th grade classes and their teachers for one-week overnight camps throughout the school year impacting over 1,000 students their first year. Each class had the opportunity to participate in the collection of GLOBE cloud observations and learning activities. Shady Creek Outdoor School continued as a strong partner throughout the project sharing the GLOBE camp opportunity with other school camps across the state of California. In addition to the GLOBE cloud class they implemented in 2021, starting in 2022 they added a GLOBE soil class as a second class offering during their school camps.

In 2023, Camp Discovery in Blythewood, South Carolina hosted the first in-person Informal GLOBE professional development (PD) with camp facilitators from across six states attending. During this PD session, GLOBE trainers Peggy Foletta, Jessica Taylor, and Tina Harte provided hydrosphere and atmosphere protocol training, with a collection of informal GLOBE learning activities designed to engage learners of all ages. **Feedback from the weeklong PD demonstrated the importance of in-person training opportunities for the success of implementation vs that of virtual workshops.**

In 2023, the NASA GLOBE Goes to Camp Summer Intense Observation Period was shared with the GLOBE community. During the months of June and July campers from 24 camps across the United States collected air temperature, soil temperature, surface temperature, and water temperature data. As a component of their observations, campers explored relationships among the GLOBE temperature protocols as they monitored differences across various microclimates found within their camp and community. Each camp had the opportunity to explore data being collected by other GLOBE camps and members of the GLOBE community, expanding their understanding of temperature data as it relates to others across the US and around the world.

During the fall of 2023, building upon the success of our first in-person PD we established a cohort of seven directors from camps that were working with camp-to-school partnerships during the 2023-2024 school year. Three of these camp directors volunteered as camp director mentors to assist the cohort in the process of working to establish STEM learning ecosystems within their communities, engage community leaders and businesses, and seek support/funding for the implementation of GLOBE both in their summer camps and in their camp-to-school partnerships. This work allowed for the continuation of the learning beyond that of summer camp, providing classrooms with the opportunity to conduct GLOBE investigations through field experiences. **The mentor camp directors helped create sustainability in our efforts by allowing our team to focus on the national level while mentors engaged camps from their state and region.**

GLOBE Goes to Camp worked with 37 camps and outdoor education centers during 2024, with two of these camps hosting Informal GLOBE professional development (PD) sessions for camp directors across the United States. The first occurred in April at Shady Creek Outdoor School in Nevada City, CA with our GLOBE Camp Mentor Mike Shanahan. The PD focused on Green-up, Tree Height, and Surface Temperature GLOBE Protocols. The second was in October 2024 hosted by the Wisconsin Lions Camp in Rosholt, WI, with our GLOBE Camp Mentor Philip

Potter. That PD spotlighted the following GLOBE protocols: Clouds, Air Temperature, Surface Temperature, Green down, Macroinvertebrates, and Water Quality. Each PD had its own unique microclimate that were great opportunities to examine GLOBE protocols through different perspectives.

As a component of the GLOBE Goes to Camp project, **facilitator learning guides were developed to provide camps with a sequence of activities and data collection developed specifically for informal audiences with customizable data sheets**. The customizable data sheets allowed camps to collect data that could be used to answer a specific investigation question that aligned with issues being faced by their local community. Each facilitator guide included the NASA "Why", the Community "Why", a comprehensive materials list, supporting learning activities, a GLOBE protocol, and data sheets. The first four guides developed aligned with the tools found on the GLOBE Observer app, these guides can be accessed on the GLOBE Observer website. In addition, guides were developed for the following protocols: air quality, phenology, surface temperature, soil, and water.

Over the course of the project **70+ camps were impacted, providing over 115K campers and their families** with the ability to connect with NASA subject matter experts (SMEs) and engage in citizen science investigations. The camps represented a variety of day, overnight, weekly, summer long and school yearlong camp programs with a variety of types of camps such as Lions camp, camps for neurodivergent learners, camps for specific genders, Tech Trek, Girl Scout Camps, YMCA summer programs, STEM Camps, and Outdoor School camps. The range of ages served within these programs were from pre-K all the way to adult. Each camp brought a unique style to how GLOBE was implemented with their campers and families giving credence to the fact that GLOBE is a program that can be implemented in any type of formal or informal learning setting.

Based upon feedback gained by our project evaluations, **the greatest impact from the project was achieved within outdoor education centers that held camps all year long**. **These camps had the capacity for more in-depth data collection with an increased focus on the development of STEM** while summer camps focused more on the activities without the collection of data. Through their work with GLOBE, these outdoor learning centers became a hub for the development of STEM learning ecosystems within their local communities.

7) ISEF NASA Earth System Science Award

NASA Langley Research Center sponsors the annual ISEF NASA Earth System Science Award. The purpose of this award is to increase awareness of the importance of scientific research in Earth system science. It is presented at regional International Science and Engineering Fairs (ISEF) around the country to middle and high school projects that best demonstrate insight into Earth's interconnected systems. From 2021 to 2025 over **650 students from across the United States were recognized** with this award.

Students who received the NASA Earth System Science Award were invited to celebrate their award with NASA career webinars where they met NASA scientists and learned how they can contribute to NASA science through citizen science.

8) Libraries

With their deep community roots, trusted status, and commitment to lifelong learning, libraries are uniquely positioned to engage learners of all ages in participatory science. From 2017 to 2025, NESEC has collaborated with over 400 libraries to implement GLOBE Observer programming in a variety of programs for audiences of all ages.

Many of our partnerships with libraries have been strengthened and facilitated through collaborations with the Space Science Institute's NASA@ My Library (NAML) Science Activation project and SSI's broader library network: STAR Net. We also supported libraries through collaborations with SciStarter's Citizen and Community Science Library Network including their library kit initiative (Mapping Mosquito Habitats) and co-presented numerous webinars targeted for library staff in collaboration with NAML and SciStarter.

NESEC has also benefitted from deeper collaborations with individual library systems and librarians: Vivienne Byrd, Los Angeles Public Library (LAPL), and Donna Blomquist, LaSalle Public Library (retired), have served as library advisors to NESEC since 2019. LAPL is a GLOBE Partner and has developed DIY Neighborhood Science Kits that can be checked out from 35 branch libraries, including three GLOBE kits (Clouds, Mosquito Habitat Mapper, and Urban Heat Island, which includes Trees). The Pioneer Library System and Southwest Oklahoma City Library hosted in-person trainings with the Mosquito Habitat Mapper team and co-presented on GLOBE Mission Mosquito webinars (See Science section 6.5.2 Challenges Held – GO Oklahoma).

LAPL has engaged in multiple GLOBE Observer data collection challenges, hosted webinars, and co-presented conference workshops and presentations (including Hyperwall talks at the NASA exhibit) with NESEC at the American Library Association meetings in 2022, 2023, 2024, and 2025, as well as at AGU Fall meetings. During the 2021 Community Trees Challenge, LAPL supported the translation of GLOBE Observer materials into Armenian, Chinese, Japanese, Korean, Persian, Russian, and Spanish to support at-home activities.

Following are major NESEC collaborations from 2021 to 2025 to partner with libraries.

- During the **2023 and 2024 Eclipse**, NESEC partnered with NASA@ My Library and GLOBE Mission Earth built a network of 100 libraries to support data collection during the eclipses. Libraries were provided with an eclipse kit consisting of equipment, safety supplies, education and outreach materials, and training. Bilingual English/Spanish kits (including Eclipse Soundscapes resources as well) went to an additional 49 libraries, and more libraries joined the network without receiving the eclipse kits.

- **2025 NUBE GLOBE Clouds Game**: The LaRC GLOBE Clouds team, worked with the Queens Public Library to co-develop and field test the NUBE GLOBE Clouds Game. Through a collaboration with NAML, over 300 U.S. libraries in 47 states were selected by application to receive 2 or 4 card decks for use in their programs beginning summer 2025 and the opportunity to attend a professional development webinar. Figure 13 shows the locations of these libraries, which included more than 50% serving rural

communities. Participating libraries completed evaluation surveys on how they are using or plan to use the NUBE. Table 7 shows their responses to a question asking the type of library program in which they are using the game. Overall the survey responses were very positive with librarians overall reporting that the game met their expectations related to ease of use, educational value, and effectiveness in teaching about clouds.

This collaboration was featured in a NASA Science news article .

Figure 13. Locations of libraries selected to receive NUBE Clouds games.

Table 7. Library Programs using NUBE (N=138)

Type of Library Program	Number
STEM program	20
Afterschool program	19
Summer programs	13
Gaming event	12

Type of Library Program	Number
Homeschool program	10
Other	9
Storytime	8
Circulating item patrons can check out	7
Citizen science programs	5
Makerspaces	4
Special event (seasonal celebrations, trivia night, etc.)	3
Arts, crafts, or creative event	1
Club	1
Community outreach events	1

- The GLOBE Observer Library Guide provides examples of library implementation of GLOBE. Also in the toolkit are resource collections that NESEC developed for iREAD programs, which had the following themes: 2025 – Level Up at Your Library (games and puzzles) and 2026 – Plant a Seed, Read. Developed by the Illinois Library Association, the iREAD program is adopted in other states including Alaska, California, Connecticut, Iowa, Louisiana, Maine, Massachusetts, Minnesota, New Hampshire, Oregon, Rhode Island, Southwest Kansas Library System, Washington, and Northern Lights Library System in Canada, and worldwide by the Department of Defense for libraries on military bases. iREAD is implemented in thousands of individual libraries across the country.

- NESEC also collaborated with the U.S. GLOBE Office at the University of New Hampshire to develop a resource guide to support the 2025 Collaborative Summer Library Program (CSLP) theme "Color Our World." CSLP includes 36 member states including Alabama, Arizona, Arkansas, Colorado, Delaware, Georgia, Idaho, Indiana, Kansas, Kentucky, Maryland, Michigan, Mississippi, Missouri, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania,

South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming

D. Strategic Partnerships and Collaborations

Strategic partnerships and collaborations with organizations are fundamental to NESEC's approach to broadening participation in the inspiring, relevant, compelling, and important work of NASA Earth science. These external partnerships and collaborations, as well as cross-collaborations within the SciAct community, grew and evolved from 2021 to 2026.

Several leveraging partnerships and collaborations are described throughout the preceding sections that engage external entities with common interests, from local to international organizations. Participation in the SciAct collective is also an important part of our work; see pages 52-54 for a summary of NESEC cross-collaborations with other SciAct awards and contributions to the SciAct collective community of practice. Appendix C. provides a list of external partners from 2021 to 2026.

II. Products

NESEC products and results were disseminated through numerous avenues, including presentations at conferences and meetings, publications, and websites.

Presentations

The NESEC team presented at numerous state, national, and international professional conferences and meetings, including the following:

Scientific and Technical Conferences and Meetings

- American Astronomical Society meeting
- American Meteorological Society Annual Meeting and AMS Weather Band Symposia
- Arctic Research Center of the U.S. (ARCUS): Community and Citizen Science in the Far North Conference
- American Geophysical Union Fall Meeting
- American Mosquito Control Association annual meetings
- Civil Air Patrol Conference
- Earth Science Information Partners (ESIP) Annual Meeting
- Entomological Society of America (ESA) Annual Meeting
- Gordon Research Conference on Visualization in Science and Education
- NASA Applied Remote Sensing Training (ARSET)
- NASA Citizen Science Leader Workshop Series
- NASA GEO Health Community of Practice
- NASA CERES Science Team Meeting
- NASA ICESat-2 Mission Applications Workshop

- NASA PMM Science Team Meeting (Precipitation Measurement Mission)
- Texas Master Naturalists Annual Meeting
- United Nations Institute for Training and Research (UNITAR)
- William T. Pecora Memorial Remote Sensing Symposium
- Wyoming Mosquito Management Association Annual Meeting

Education Conferences and Meetings

- 21st Century Community Learning Centers Summer Symposia
- American Camp Association National and Regional Conferences
- American Library Association annual meeting
- American Philosophical Society Symposium on Citizen Science
- AwesomeCon, Washington, D.C.
- C*Sci and Conference for the Advancement of Participatory Science (CAPS)
- Data Science Education K-12 Research to Practice Conference
- GLOBE Annual meetings, Student Learning Symposia, North America and other GLOBE Regional Meetings
- Lunar and Planetary Institute Virtual Exploration Experiences with Planetary Scientists (VEEPS)
- Maryland Association for Outdoor Environmental Education
- Massachusetts Library Association Meeting
- Mountain Science Expo at NC Arboretum
- NASA Earth Day celebrations
- National Association for Interpretation
- National Science Teaching Association (NSTA) National and Regional Conferences
- North American Association for Environmental Education (NAAEE) Conference
- Odyssey of the Mind World Finals
- Project Learning Tree/WET/WILD Annual Conference
- Satellites & Education Conference
- South Dakota STEM Education Conference
- Space Exploration Educators Conference
- STEM Learning Ecosystems
- Maryland STEM Festival event
- Virginia Master Naturalist conference

Publications

From 2021 to 2025 there were a total of 38 NESEC-related publications. Appendix A provides a listing of all NESEC-related publications from 2017 to 2026, which are summarized in Table 8.

Table 8 NESEC Publications 2017-2026

NESEC Publications from 2017-2026 (number peer-reviewed in parentheses)			
2026 *In Process*	2021-2025	2017-2020	Total Publications
7 (4)	38 (31)	17 (10)	62 (45)

The totals shown in Table 8 include:

- 2026: 7 papers in process for publication in 2026 and include 2 in review, 3 submitted to an edited volume on the GLOBE Program by Springer, and 2 that have been approved for submission and are being prepared for submission.
- 2021-2025: 8 publications with students as either 1st authors or co-authors, and 9 publications not written by NESEC team members but acknowledge using GLOBE Observer data.
- 2017-2020: 1 publication not written by NESEC team members but acknowledges GLOBE Observer data.

Websites

- GLOBE Observer, observer.globe.gov
- Trees Around the GLOBE Student Research Campaign website, https://www.globe.gov/web/trees-around-the-globe
- GLOBE Mission Mosquito, https://www.globe.gov/web/mission-mosquito/overview

Other Products (e.g., education products, guides, datasets, etc.)

Products developed by the NESEC team, including education products, guides, tutorials, and curated datasets from data challenges are available on the websites listed above, and are also identified in earlier sections of this report.

The following products are not applicable:

- Technologies or techniques
- Inventions, patent applications, and/or licenses

III. Participants & Other Collaborating Organizations

NESEC Partner Organizations:

NASA Goddard Space Flight Center
NASA Langley Research Center
NASA Jet Propulsion Laboratory

Oregon State University STEM Research Center is the NESEC external evaluator. Appendix A provides a roster of all NESEC team members from 2016 to 2026.

NESEC Partners and Collaborating Organizations
NESEC annual external partner reports for SciAct included 40 external organizations and partners. These strategic partnerships represent significant relationships between the NESEC team and external organizations with a common purpose or joint output (e.g., co-authors on a paper, co-developing an educational resource, conducting a citizen science campaign, developing enhanced tools, funded research using GLOBE Observer data, etc.). Appendix C includes a list of the 40 external partners that NESEC worked with from 2021 to 2025.

IV. Changes/Problems - None to Report

V. Cross-Collaboration Agreements Activities

From 2021 to 2025, NESEC collaborated with 22 projects across the SciAct collective, including signed cross-collaboration statements with 15 projects. NESEC cross-collaborations included a wide range of activities, which are captured in Table 9 and categorized as follows:

- **Programmatic:** Collaborated to co-design or co-deliver a program or experience.
- **Resource Sharing:** Shared assets from NESEC or used assets from other projects.
- **Knowledge Sharing:** Provided guidance (e.g., audience needs, science content) or feedback (e.g., identify/provide SMEs, review resources, etc.).
- **Dissemination:** Distributed resources or shared information with audiences and networks of practitioners (e.g., share information through listservs, enews, at conferences and workshops, shipping materials, etc.).

Working collaboratively with other SciAct teams enabled NESEC to:

- Work more efficiently and effectively (e.g., University of Texas-Austin, provided recruitment, selection, and overall administration of the SEES internships); share workloads and costs - e.g., NESEC provided thermometers for NASA eClips GLOBE teacher PD; co-presented webinars and held joint office hours with Eclipse Soundscapes; and numerous joint webinars and workshops with NIA, GLOBE Mission Earth, NAML, Earth to Sky, etc. For the 2023 and 2024 solar eclipses, NASA@ My Library and the Eclipse Ambassadors projects recruited and shipped GLOBE Eclipse kits to hundreds of libraries and ambassadors across the U.S.)
- Leverage SciAct teams' extensive networks and deep knowledge of audiences (e.g., NASA@ My Library, Earth to Sky, NISEnet, Solar System Ambassadors, NASA Museum and Informal Education Network, etc.).
- Broaden our reach, including reaching more diverse audiences (e.g., multi-sensory observing with Eclipse Soundscapes and reaching rural populations through collaborations with NAML).
- Create deeper connections for audiences to GLOBE and NASA Earth science missions.
- Make interdisciplinary connections (NASA HEAT, Night Sky Network, and Earth to Sky).

Table 9. NESEC Cross-Collaborations with SciAct Community 2021-2025. Projects asterisked had signed statements of collaboration with NESEC.

Collaborating SciAct Team	Years active (1-5)	Programmatic	Expertise Sharing	Resource Sharing	Dissemination
*American Camp Association Collaboration	5	X	X	X	X
*Arctic and Earth SIGNS	5	X	X	X	X
*Earth to Sky	5	X	X	X	X
*GLOBE Mission Earth	5	X	X	X	X
*NASA eClips	5	X	X	X	X
*NASA HEAT	5	X	X	X	X
*NASA@ My Library	5	X	X	X	X
*National Informal STEM Education Network (NISEnet)	5	X	X	X	X
*STEM Enhancement in Earth Sciences (SEES)	5	X	X		
STEM Learning Ecosystems	5		X	X	
*Engaging Hispanic Audiences	5 (2021-2025)		X	X	
AREN Project	4 (2021-2024)		X	X	
SCoPE	4 (2021-2024)	X	X		
Solar System Ambassadors	4 (2021-2024)				X
Museum and Informal Education Alliance	4 (2021-2024)				X
Night Sky Network	4 (2021-2024)	X	X	X	X
*Learning Ecosystems Northeast	3 (2022-2024)	X	X	X	X

Collaborating SciAct Team	Years active (1-5)	Programmatic	Expertise Sharing	Resource Sharing	Dissemination
*Earth Odyssey/Challenger Center	2 (2023-2024)		X	X	
*Eclipse Ambassadors	2 (2023-2024)	X	X	X	X
*Eclipse Soundscapes	3 (2022-2024)	X	X	X	X
Navigating the Path of Totality (Exploratorium)	2 (2023-2024)	X		X	
*NASA's Neurodiversity Network	1 (2021)		X	X	

VI. Evaluation: Impact and Project Outcomes

The NESEC summative evaluation report by Oregon State University STEM Research Center is provided in a separate report. An executive summary of this report is included as Appendix E.

Appendix A: NESEC Publications 2017-2026

Peer-reviewed publications are indicated with a red asterisk (*). Publications co-authored with or by interns are indicated with double asterisk (**** or ** if peer reviewed**). Intern/student author names are identified in red.**

This section includes:

- Papers Submitted or In Process as of February 15, 2026
- 2021 to 2026 Publications
- 2017 to 2020 Publications
- Other Relevant Publications

Papers Submitted or In Process as of February 15, 2026

In review (November 2025): Schwerin, T., Nyman, M., Fischer, H., and Martin, A. Submitted to the Journal Citizen Science Theory and Practice: Special Collection on 'Lessons, Challenges, and Opportunities in Participatory Science from a Galleries, Libraries, Archives, Museums'.

In review (January 2026) Yang D, Huang X, Mitchell J, He Y, Nelson P, Low P. Chapter 16 Title: How Citizen Science and New Technologies can Integrate with Big Data-Subtitle: Empowering Public Participation in Geospatial Research and Environmental Monitoring. Remote Sensing, Big Data, and GeoAI, Integration of Remote Sensing, Big Data, and GeoAI. Elsevier.

Submitted (January 2026): Three GLOBE Observer chapters have been submitted for a volume about the GLOBE Program to be published by Springer: 1) The Role of Partnerships in Developing the GLOBE Observer App and Expanding the GLOBE Community (lead author: Kristen Weaver), 2) Complementary Perspectives on Clouds: Integrating GLOBE Citizen Science and Satellite Data, and 3) From Local Voices to Global Vision: How Community Action Sparked an International Science Project (lead author: Rusty Low).

In Process: Proposals approved by the Bulletin of the American Meteorological Society (BAMS) for two manuscripts related to the Civil Air Patrol Aviation Weather mission.

2021 to 2026 Publications

*Abdelkader, M., Bravo Mendez, J., Temimi, M., Brown, D., Spellman, K., Arp, C., Bondurant, A., & Kohl, H. (2024). **A Google Earth Engine Platform to Integrate Multi-Satellite and Citizen Science Data for the Monitoring of River Ice Dynamics**. In Remote Sensing (Vol. 16, Issue 8, p. 1368). MDPI AG.https://doi.org/10.3390/rs16081368

Agrawal, N., Nelson, P.V., and Low, R.D. (2023). **A Novel Approach for Predicting Large Wildfires Using Machine Learning towards Environmental Justice via Environmental Remote Sensing and Atmospheric Reanalysis Data across the United States" Remote Sensing 15, no. 23: 5501. https://doi.org/10.3390/rs15235501

*Autore, A. M., Dodson, J. B., Duda, D. P., Robles, M. C., Weaver, K. L., Taylor, J. E., Rogerson, T. M., & Kohl, H. (2025). **GLOBE Eclipse 2024: A Case Study of the Effects of the April 2024 Total Solar Eclipse on Cirrus Clouds and Contrails in the United States of America.** Bulletin of the AAS, 56(9). https://doi.org/10.3847/25c2cfeb.d9ddc39b

*Campbell, B., (2021). I**CESat-2 and the Trees Around the GLOBE student research campaign: Looking at Earth's tree height, one tree at a time**. In Acta Astronautica, Volume 182, Pages 203-207. https://doi.org/10.1016/j.actaastro.2021.02.002

*Carney, R. M., Azam, F., Gehrisch, K., Bhuiyan, T., Rafarasoa, L. S., Riantsoa, V., Low, R. D., Zohdy, S., Andrianjafy, T. M., Ramahazomanana, M. A., Rasolofo, R. N., Subramani, P. A., Ogbondah, M., Uelmen, J. A., Jr., & Chellappan, S. (2025). **Artificial Intelligence and Citizen Science as a Tool for Global Mosquito Surveillance: Madagascar Case Study**. *Insects*, *16*(11), 1098. https://doi.org/10.3390/insects16111098

*Carney, R.M., Long, A., Low, R.D., Zohdy, S. Palmer, J.R.B., Elias, P, Bartumeus, F., Njoroge, L, Muniafu M., Uelman, J.A., Rahola, N. and Chellappan, S. **Citizen science as an approach for responding to the threat of Anopheles stephensi in Africa.** Citizen Science: Theory and Practice.

*Carney, R., Mapes, C., Low, R., Long, A., Bowser, A., Durieux, D., et al. (2022). **Integrating Global Citizen Science Platforms to Enable Next-Generation Surveillance of Invasive and Vector Mosquitoes**. *Insects*, *13*(8), 675. https://doi.org/10.3390/insects13080675

*Chambers, L., Connolly, R., Kirk, M., Fischer, H.,...Kohl, H., Schwerin, T. et al. (2025) **Uniting Under the Eclipse: A Mega-Collaboration to Activate Science Learning Across the Penumbra and Beyond**. Holli Kohl and Theresa Schwerin are co-authors. Bulletin of the AAS, 57. https://doi.org/10.3847/25c2cfeb.52359797

*Cho, H., Low, R., Fischer, H., and Storksdieck, M. (2021). **The STEM Enhancement in Earth Science "Mosquito Mappers" Virtual Internship: Outcomes of Place-Based Engagement with Citizen Science**. Frontiers in Environmental Science. https://www.frontiersin.org/articles/10.3389/fenvs.2021.682669/full

Colón Robles, M. (2021, July/August). **Cloud Watching for NASA**. Cricket MUSE Science and Exploration for Inquisitive Minds, 25, 26-27.

*Dodson, J. B., Robles, M. C., Rogerson, T. M., & Taylor, J. E. (2022). **Do citizen science Intense Observation Periods increase data usability?** A deep dive of the NASA GLOBE Clouds data set with satellite comparisons. Earth and Space Science, 9, e2021EA002058. https://doi.org/10.1029/2021EA002058

*Edson, LB, MacDonald, E, Cawood, A and Fischer, H. (2024). **Practical Applications of a Participatory Science Project Evaluation Tool:** Perspectives from Across Earth and Space Science. Citizen Science: Theory and Practice, 9(1): 10, pp. 1–11. https://doi.org/10.5334/cstp.536

*Enterkine, J., Campbell, B.A., Kohl, H., Glenn, N.F., Weaver, K., Overoye, D., and Danke, D. (2022). **The potential of citizen science data to complement satellite and airborne lidar tree height measurements: lessons from The GLOBE Program**. Environmental Research Letters, 17 (7). https://doi.org/10.1088/1748-9326/ac77a2

*Fischer, H., Cho, H. and Storksdieck, M., 2021. **Going Beyond Hooked Participants: The Nibble-and- Drop Framework for Classifying Citizen Science Participation**. Citizen Science: Theory and Practice, 6(1), p.10. http://doi.org/10.5334/cstp.350

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*Huang, X., Yang, D., He, Y., Nelson, P., Low, R., McBride, S. Mitchell, J., and Guarraia, M. (2023). **Land cover mapping via crowdsourced multi-directional views**: The more directional views, the better, International Journal of Applied Earth Observation and Geoinformation, Volume 122, 103382, SSN 1569-8432https://authors.elsevier.com/sd/article/S1569-8432(23)00206-6

Kar, K. and Low, R. (2021). **The effect of poverty on mosquito-borne illness across the United States. Journal of Emerging Investigators, 3, 1-7.

*Kohl H.A., Nelson P.V., Pring J., Weaver K.L., Wiley D.M., Danielson A.B., Cooper R.M., Mortimer H., Overoye D., Burdick A., Taylor S., Haley M., Haley S., Lange J., and Lindblad M.E. (2021). **GLOBE Observer and the GO on a Trail Data Challenge: A Citizen Science Approach to Generating a Global Land Cover Land Use Reference Dataset.** Front. Clim. 3:620497. https://doi.org/10.3389/fclim.2021.620497

Low, R.D.; Schwerin, T.G.; Boger, R.A.; Soeffing, C.; Nelson, P.V.; Bartlett, D.; Ingle, P.; Kimura, M.; Clark, A. (2022). **Building International Capacity for Citizen Scientist Engagement in Mosquito Surveillance and Mitigation: The GLOBE Program's GLOBE Observer Mosquito Habitat Mapper. Insects 2022, 13, 624.https://doi.org/10.3390/insects13070624

Low, R., Nelson, P.V., Soeffing C., Clark A., SEES 2020 Mosquito Mappers Research Team. (2021). **Adopt a Pixel 3 km: A Multiscale Data Set Linking Remotely Sensed Land Cover Imagery With Field Based Citizen Science Observation. Frontiers in Climate. https://doi.org/10.3389/fclim.2021.658063

Low, R., Boger, R., Nelson, P., and Kimura, M. (2021). **GLOBE Observer Mosquito Habitat Mapper Citizen Science Data 2017-2020. GeoHealth. https://doi.org/10.1029/2021GH000436

Low, R. (2020), **Zika Zine: A Resource Promoting the Integration of STEAM and Literacy in the Classroom**. The Earth Scientist 36(1): 6-8.

*Lu M-K, Popescu S.C., and Campbell, B.A. (2025). **Use of GLOBE observer citizen science data to validate continental-scale canopy height maps derived from ICESat-2 and GEDI**. Front. Environ. Sci. 13:1635707. https://doi.org/10.3389/fenvs.2025.1635707

*Nelson, P. V., Low, R., Kohl, H., Overoye, D., Yang, D., Huang, X., Chellappan, S., Azam, F. B., Carney, R.M., Falk, M., Garriga, J., Schelkin, L., Boger, R., Schwerin, T. (2024). **GLOBE Observer: A Case Study in Advancing Earth System Knowledge with AI-Powered Citizen Science**. Citizen Science: Theory and Practice, 9(1), 33. https://doi.org/10.5334/cstp.747

*Patil, Y., Fathima, R., Campbell, B., Janney, D., Hudnurkar, S., R, H. (2024). **Review of earth observation techniques and citizen science approach for biodiversity hotspot study.** International Journal of Environmental Impacts, Vol. 7, No. 4, pp. 753-767. https://doi.org/10.18280/ijei.070416

Polineni, S., Shastri, O., Bagchi, A., Gnanakumar, G., Rasamsetti, S., & Sundaravadivel, P. (2022) **MOSQUITO EDGE: An Edge-Intelligent Real-Time Mosquito Threat Prediction Using an IoT-Enabled Hardware System. *Sensors*, *22*(2), 695.

Sun, C., Nimbalkar, J., & Bedi, R. (2022). **Predicting future mosquito larval habitats using time series climate forecasting and deep learning. Proceedings of the IEEE MIT Undergraduate Research Technology Conference (URTC). Institute of Electrical and Electronic Engineers. https://doi.org/10.1109/URTC56832.2022.10002240 (SEES 2021 Interns)

*Uelmen, J.A., Clark, A., Palmer, J. Kohler, J., Van Dyke, L.C., Low, R.D., Mapes, C.D., and Carney, R.M. (2023). **Global mosquito observations dashboard (GMOD)**: creating a user-friendly web interface fueled by citizen science to monitor invasive and vector mosquitoes. *Int J Health Geogr* 22, 28. https://doi.org/10.1186/s12942-023-00350-7

Xia, I., Singirikonda, N., Hellman, L., Watson, J., Hanna, M. and Low, R. (2022). **Using Machine Learning Regressors for the Discovery of Culex Mosquito Habitats and Breeding Patterns in Washington DC. Journal of Student Research, 11(4). https://doi.org/10.47611/jsrhs.v11i4.3710

2017 to 2020 Publications

*Amos, H. M., Starke, M. J., Rogerson, T. M., Colón Robles, M., Andersen, T., Boger, R., et al. (2020). **GLOBE Observer data: 2016–2019.** Earth and Space Science, 7, e2020EA001175.https://doi.org/10.1029/2020EA001175

*Boger, R., Low, R., and Nelson, P. ***Identifying hurricane impacts on Barbuda using citizen science ground observations, drone photography and satellite imagery.*** The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences; Gottingen Vol. XLII-3/W11, : 23-28. Gottingen: Copernicus GmbH. (2020). DOI:10.5194/isprs-archives-XLII-3-W11-23-2020 https://isprs-archives.copernicus.org/articles/XLII-3-W11/23/2020/

***Burck, L., and Soeffing, C. (2019). Phenomena-Based Student Investigations with NASA Earth Observations in The Earth Scientist, vol 35, no. 1, pp 26-34. https://www.strategies.org/wp-content/uploads/2019/04/Burck_FINALRevApril24.pdf**

*Colón Robles, M., Amos, H.M., Dodson, J. B., Bouwman, J., Rogerson, T., Bombosch, A., Farmer, L., Burdick, A., Taylor, J., and Chambers, L. H. (2020). ***Clouds around the World: How a Simple Citizen Science Data Challenge Became a Worldwide Success.*** *Bull. Amer. Meteor. Soc.* **101** (7): E1201–E1213.https://doi.org/10.1175/BAMS-D-19-0295.1

*Colón Robles, M., Bouwman, J., and Smith-Long, C. (2019) ***Integrating Tech: Making Science Come Alive with Clouds.*** NSTA Science Scope, vol. 43, no. 4, November 2019. pp. 8-12. https://observer.globe.gov/documents/19589576/52621820/NSTA+Science+SCOPE+Integrating+Tech+with+Clouds/8da3cd4b-8832-47e4-85f4-feee021b7fdb

*Dodson, J.B., Colón Robles, M., Taylor, J.E., DeFontes, C.C., and Weaver, K.L. **"Eclipse Across America: Citizen Science Observations of the 21 August 2017 Total Solar Eclipse."** J. Appl. Meteor. Climatol. (2019) 58 (11): 2363–2385. https://doi.org/10.1175/JAMC-D-18-0297.1

*Fischer, H., Cho, H., and Storksdieck, M. 2021. **Going Beyond Hooked Participants: The Nibble-and-Drop Framework for Classifying Citizen Science Participation**. Citizen Science: Theory and Practice, 6(1): 10, pp. 1–18. DOI: https://doi.org/10.5334/cstp.350

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*Lin, D.W. (2020) **Land Cover Feature Analysis for Mosquito Habitats**. IOSR Journal of Environmental Science, Toxicology and Food Technology. e-ISSN: 2319-2402,p- ISSN: 2319-2399. Volume 14, Issue 12 Ser. II (December 2020), p 24-30. https://www.academia.edu/44798039/Land_Cover_Feature_Analysis_for_Mosquito_Habitats?email_work_card=thumbnail

*Muñoz, J.P., Boger, R., Dexter, S., and Low, R. (2019) ***Mosquitoes and Public Health: Improving Data Validation of Citizen Science Contributions Using Computer Vision*** In N. Wickramasinghe and F. Bodendorf (Eds), Healthcare Delivery in the Information Age Series) https://link.springer.com/chapter/10.1007/978-3-030-17347-0_23

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Weaver, K., Davis A., & Giddens, J. (2019, September/October). **Can an app change how you see the world? GLOBE Observer for interpreters.** Legacy: The magazine of the National Association for Interpretation, 30(5), 20-23. https://observer.globe.gov/documents/19589576/50520851/Legacy+Magazine+-+Sep-Oct+2019+GO+Article+Abstract/97505810-eee2-4abb-9224-764ea987d3bd

Weaver, K., Kohl, H., Martin, A., & Burdick, A. (2019). **How cool was the eclipse? Collecting Earth science data with citizen scientists and GLOBE Observer.** In S.R. Buxner, L. Shore, & J.B. Jensen (Eds.), Celebrating the 2017 Great American Eclipse: Lessons learned from the path of totality (pp. 511-524). Astronomical Society of the Pacific Conference Series. http://www.aspbooks.org/a/volumes/article_details/?paper_id=39751

Other Relevant Publications

These include publications that use GLOBE Observer data or protocols, acknowledge the GLOBE Observer team (e.g., papers by projects that collaborated with NESEC, e.g., EPSCoR or NASA Earth System Citizen Science), or publications by SEES Earth System Explorers interns that do not include NESEC team members as co-authors.

*Brown, D. R. N., Arp, C. D., Brinkman, T. J., Cellarius, B. A., Engram, M., Miller, M. E., & Spellman, K. V. (2023). **Long-term change and geospatial patterns of river ice cover and navigability in Southcentral Alaska detected with remote sensing**. *Arctic, Antarctic, and Alpine Research*, 55(1). https://doi.org/10.1080/15230430.2023.2241279

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*Freeman, E.A., Carlton, E.J., Paull S., Dadzie, S., Buchwald, A. (2022). **Utilizing citizen science to model the distribution of Aedes aegypti in West Africa**. J. of Vector Ecology, 47(1):117-127. https://doi.org/10.52707/1081-1710-47.1.117

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*Manzanarez, S., Manian, V., and Santos, M. (2022). **Land Use Land Cover Labeling of GLOBE Images Using a Deep Learning Fusion Model**. Sensors 2022, 22 (18), 6895. https://doi.org/10.3390/s22186895

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*Tsao, A., Nzewi, I., Jayeoba, A., Ayogu, U., & Lobell, D. B. (2023). **Canopy Height Mapping for Plantations in Nigeria Using GEDI, Landsat, and Sentinel-2. Remote Sensing**, 15(21), 5162. https://doi.org/10.3390/rs15215162

Appendix B: NESEC Team Roster 2016-2026

Institute for Global Environmental Strategies
Theresa Schwerin, PI (2016-2026)
Russanne Low (2016-2026)
Cassie Soeffing (2016-2026)
Andrew Clark (2016-2026)
Brianna Lind (2025)
Liz Burck (2016-2023)

Interns
Nikita Agrawal (2023)
Matteo Kimura (2021)
Prachi Ingle (2021)
Pratham Barbaria (2021)

NASA Goddard Space Flight Center
Trena Ferrell, Co-PI (2016-2026)
Holli Kohl (2016-2026)
Kristen Weaver (2016-2026)
Brian Campbell (2016-2026)
Heather Mortimer (2018-2026)
Dorian Janney (2016-2025)
Agnes Conaty (2022-2025)
Jeannie Allen (2016-2020)
Helen Amos (2018-2020)
Tassia Owen (2016-2022)
Ginger Butcher (2016-2018)
Eric Brown deColstoun (2018-2020)
Christopher Shuman (2017-2021)
Allegra LeGrande (2017-2021)
Dot Zukor (2016)

Interns
Naudia Graham (2022)
Siddharth Jasti (2023)
Jessica Mo (2023)
Allison Swann (2022)
Matthew Starke (2019)

NASA Langley Research Center
Jessica Taylor, Co-PI (2016-2026)
Marilé Colón Robles (2017-2026)

Margaret Pippin (2016-2025)
Tina Rogerson (2016-2026)
Barbara Buckner (2025)
Ashlee Autore (2024-2025)
Rosalba Giarratano (2022-2026)
Tina Ballinger (2016-2026)
Brant Dodson (2018-2019)
Angie Rizzi (2018-2022)
Jason Welsh (2021-2022)
Lin Chambers (2016-2017)
Sarah McCrea (2016-2017)
Ann Martin (2016-2017)

Interns
Logan Butler (2025)
Roger Rose, Teacher intern (2023)
Naudia Graham (2022)
Olivia Ferrare (2019)
Kevin Ivey (2019)
Ryan Moore
Cayley Cruickshank

Jet Propulsion Laboratory
Susan Callery, Co-PI (2016-2021)
Peter Falcon (2016-2025)
Erika Podest (2016-2025)
Rachel Zimmerman Brachman (2017-2021)
Steve Edberg (2017)

Interns
Kenan Arica (2019)
Jacqueline Castellanos (2019)

Oregon State University: STEM Research Center
Martin Storksdieck (2016-2026)
Heather Fischer (2018-2026
Matthew Nyman (2020-2026)
Holly Cho (2020-2024)
Nancee Hunter (2018-2019?)

Oregon State University: College of Earth, Ocean, and Atmospheric Sciences
Peder Nelson (2017-2026)

GLOBE Data and Information System
Lisa Dallas, NASA Task Manager for the GLOBE DIS contract

GLOBE DIS contract: team members that worked on GLOBE Observer

David Overoye (2016-2025)
Cornell Lewis (2016-2025)
Autumn Burdick (2017-2024)
Harman Smith (2016-2025)
Joe Wieclawek (2016-2026)
John Schimmels (2016-2026)
Daniel Balandran
Benny Chan
Sean Graham
Liz Johnson
Bryan Littlefield
John Schimmels
Donovan Theseira
Ashwin Ravindran
Jessica Beelie
Eve Terrill
Kyle Liu
Ben Luker
Stella Xsin
Angelina Tsai
Tessa Clougherty
Andrew Clifford
Adarsh Ravindran

Appendix C: NESEC External Partners 2021-2025

Following are external partners that were included in our annual partner report. In addition to these groups, we also had hundreds of collaborations with local organizations including camps, libraries, schools, Girl Scout troops, parks, and others.

External Partner	Years Active	Brief Description
Accenture	2022-2024	Corporate employee volunteer engagement program by an international corporation that conducted GLOBE Observer data collection campaigns. NESECE supported this initiative with two to four webinars annually.
AMS Project Atmosphere	2021-2025	AMS hosts the Project Atmosphere teacher workshop focused in atmospheric sciences where NESEC presents how to make cloud observations and activities that help in the identification of cloud types.
ENGAGING AND INSPIRING CAMP DISCOVERY	2021-2024	As part of GLOBE Goes to Camp, Camp Discovery was a lead mentor for other camps and co-developed GLOBE pacing guides for camp programs.
Chesapeake Bay Foundation's Keystone 10 Million Trees	2024-2025	The Trees Around the GLOBE campaign lead worked with this group to take tree height observations at tree planting sites and compare with NASA satellite data.
CIVIL AIR PATROL U.S. AIR FORCE AUXILIARY	2023-2025	Collaborated with NESEC on: ● 2023 and 2024 solar eclipses ● 2025 Aviation Weather Mission ● Response Mappers ● Co-presenters at conferences and Co-authors on publications
El Paso Community College	2024-2025	GLOBE Partner and Physics professor, John Olgin, conducted scientific outreach in Latin American communities for the 2023 and 2024 eclipses. Olgin also conducted his PhD research on data quality and GLOBE Observer.
GLOBE Program/GIO	2021-2025	While GLOBE Observer was incubated under NESEC, it is part of the GLOBE Program and the team worked closely with the GLOBE Program and GLOBE Implementation Offices.

External Partner	Years Active	Brief Description
GLOBE Regional Coordination Office for Europe and Eurasia	??-2025	Trees Around the GLOBE Student Research Campaign coordinated with the European Phenology Campaign.
LaSalle Public Library	2021-2024	Advisor to NESEC, reviewed and provided feedback on NESEC-developed resources and their use in public libraries.
LOS ANGELES PUBLIC LIBRARY	2021-2025	LAPL served as an advisor and partnered with NESEC on numerous activities, co-developed resources, and co-presentated at national conferences (e.g., American Library Association and AGU). Examples include: ● Developed circulating DIY Neighborhood Science kits that are available at 35 branch libraries including kits for GLOBE Observer Clouds, Mosquito Habitat, and Urban Heat Island/Trees. ● Hosted webinars and local events for the public about NASA science, which included presentations on NASA's NISAR mission by local NESEC team members at JPL. ● Reviewed and provided feedback on NESEC-developed resources. ● Translated resources for GLOBE Observer Clouds and Trees data collection challenges.
Millersville Lifelong Learning Institute	2024	Hosted courses taught by the NESEC team for adults aged 50+.
Montgomery College Lifelong Learning Institute	2024	Hosted courses taught by the NESEC team for adults aged 50+.
eco EXPLORE an initiative of The NC Arboretum	2023-2025	The NC Arboretum partnered with NESEC on several activities: ● Hosted an eclipse day event on April 8, 2024, that was attended by over 1,500 people. ● Incorporated GLOBE Observer Clouds, Trees, and Mosquito Habitat Mapper in ecoEXPLORE challenges and badges. ● Hosted four webinars for families presented by NESEC team members. ● Included NESEC in the 2025 Mountain Science Expo, which included over 1,000 participants.
New Mexico State University	2022-2023	Funded by NASA's Established Program to Stimulate Competitive Research (EPSCoR), to conduct collaborative research through Goddard's AI Center for Excellence using GLOBE Observer land cover photos to train learning algorithms that predict and label features in the photos.

External Partner	Years Active	Brief Description
Odyssey of the Mind	2021-2025	OoTM hosted NASA science presentations, classroom workshops, and tabling activities by the NESEC team during OoTM World Finals
Osher Lifelong Learning Institute - U of Hawaii Manoa	2023-2025	Hosted virtual (online) courses taught by NESEC team for adults aged 50+. The courses were open to adults enrolled in OLLI courses across the U.S.
Osher Lifelong Learning Institute at University of South Dakota	2024	Hosted in-person courses taught by NESEC team for adults aged 50+.
THE POLAR CITIZEN SCIENCE COLLECTIVE	2021-2025	PSC works with the polar tourism industry to make contributions to scientific research through citizen science, including GLOBE Cloud observations.
QUEENS PUBLIC LIBRARY	2024-2025	QPL worked with the GLOBE Clouds team to ● Co-developed and field-test the NUBE Clouds game. ● Co-present at a GLOBE Observer Connect Webinar and STARnet Libraries Webinar ● Offer clouds related programs
SciStarter Science we can do together.	2021-2025	SciStarter hosts a partner gateway for NASA GLOBE, developed, tested, and disseminated a "Mapping Mosquitoes" library kit, and promoted GLOBE Observer citizen science activities by hosting webinars, posting blogs, and calendar events. SciStarter also teamed up with the Girl Scouts to curate projects and provide training and support for girls, volunteers, and others to deepen their engagement in citizen science and explore outdoor STEM. GLOBE Observer was one of the projects that Girl Scouts could do as part of the Girl Scout Climate Challenge (GLOBE Clouds), Girl Scout Tree Promise (GLOBE Trees), and Think Like a Citizen Scientist Journey (GLOBE Mosquito Habitat Mapper and Clouds).
TEXAS Master Naturalist™	2023-2024	NESEC partnered with Texas Master Naturalists to create a cadre of Eclipse Educators who led efforts to inspire and engage Texans of all ages to safely observe and understand the science behind the 2023 and 2024 solar eclipses by participating in GLOBE Eclipse citizen science. TMN also provided input on best practices for engaging lifelong

External Partner	Years Active	Brief Description
		learners in citizen science. Over 70 TMNs participated as Eclipse Educators.
YLACES/U.S. Department of State 	2023-2025	NESEC Partnered with a GLOBEPlus Post project with U.S. embassies in Bahamas, Costa Rica, Panama, and Guatemala. GLOBEPlus Posts is an initiative of Youth Learning as Citizen Environmental Scientists (YLACES) with the U.S. Department of State. As part of the GLOBE Mission Mosquito campaign, NESEC provided professional development webinars (simulcast in Spanish) and resources related to the Mosquito Habitat Mapper, participated in a What's App group, and provided a Mighty Networks group for ongoing discussions. The U.S. Embassy in Costa Rica also translated resources into Spanish for use with local communities and developed a GLOBE Education Guide for elementary, middle, high school instruction.
 University of Alaska, Fairbanks	2023-2025	Fresh Eyes on Ice engages communities in monitoring river ice using (among other things) the Land Cover tool in the GLOBE Observer app.
University of Florida, Gainesville	2024-2025	NASA ROSES award using GLOBE MHM data. EMERGE Curriculum: Environmental Science Meets Community Action Open Access Textbook -GLOBE data to explore mosquito-borne disease, environmental change, and public health.
University of Puerto Rico	2022-2023	Funded by NASA EPSCoR to conduct collaborative research through Goddard's AI Center for Excellence using GLOBE Observer land cover photos to train learning algorithms. Peer-reviewed paper published in *Sensors*.
University of South Florida	2021-2025	Co-authored 4 peer-reviewed publications with Dr. Rusty Low, NESEC science lead for GLOBE Observer Mosquito Habitat Mapper (MHM). USF used GLOBE MHM data in their NSF-sponsored research and served as subject matter experts presenting at NESEC webinars and reviewing MHM materials.
NASA SCoPE CONNECTING SMES AND SCIACT	2023	Partnered on SCoPE seed grant for "Building STEM Equity through Sensor Development in East Texas." The UT Tyler team conducted a one-day build-a-thon for community

External Partner	Years Active	Brief Description
University of TX-Tyler, SCoPE Seed Grant		college and high school students to train and engage students in building and testing Science and Technology Education for Land/Life Assessment (STELLA) DIY spectrometers , with virtual presentations by NESEC team making connections to GLOBE Mosquito Habitat Mapper and Land Cover.
NASA SCoPE CONNECTING SMES AND SCIACT Shaw University, Lead for SCoPE Seed Grant for 2024 Eclipse HBCU partners included: ● Alcorn State University ● Central State University ● Harris-Stowe University ● Houston-Tillotson University ● Philander-Smith University ● Wiley College	2023-2024	Partnered on a SCoPE Seed Grant award to engage Historically Black Colleges and Universities on or near the path of totality for the 2024 eclipse in doing citizen science with GLOBE Eclipse and Eclipse Soundscapes. NESEC provided training, equipment (digital thermometers), and support for participating HBCUs.
University of Vermont	2022-2024	Funded by NASA EPSCoR to conduct collaborative research through Goddard's AI Center for Excellence using GLOBE Observer land cover photos to train learning algorithms that predict and label features in the photos.
University of Wyoming	2022-2024	Funded by NASA EPSCoR to conduct collaborative research through Goddard's AI Center for Excellence using GLOBE Observer land cover and mosquito habitat mapper photos to train learning algorithms that predict and label features in the photos.
 ● USDA Forest Service ● NASA Next Gen STEM ● Artemis Program Social Media team	2022-2024	The NESEC GLOBE Observer team hosted the 2023 NASA Moon Trees Quest in collaboration with USDA Forest Service, and NASA Next Gen STEM in support of the Artemis Program. NESEC also supported the NASA STEM Artemis Moon Trees program with GLOBE Trees resources and presentations at dedication ceremonies by Moon Tree Stewards.

External Partner	Years Active	Brief Description
USDA Forest Service Geospatial Technology and Applications Center	2024-2025	NESEC's Trees Around the GLOBE Student Research Campaign collaborated with USDA Forest Service's Geospatial Technology and Applications Center about including GLOBE Trees observations in its outreach to schools.

Appendix D: References

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Appendix E: NESEC Evaluation Executive Summary

NASA EARTH SCIENCE EDUCATION COLLABORATIVE SUMMATIVE EVALUATION SUMMARY

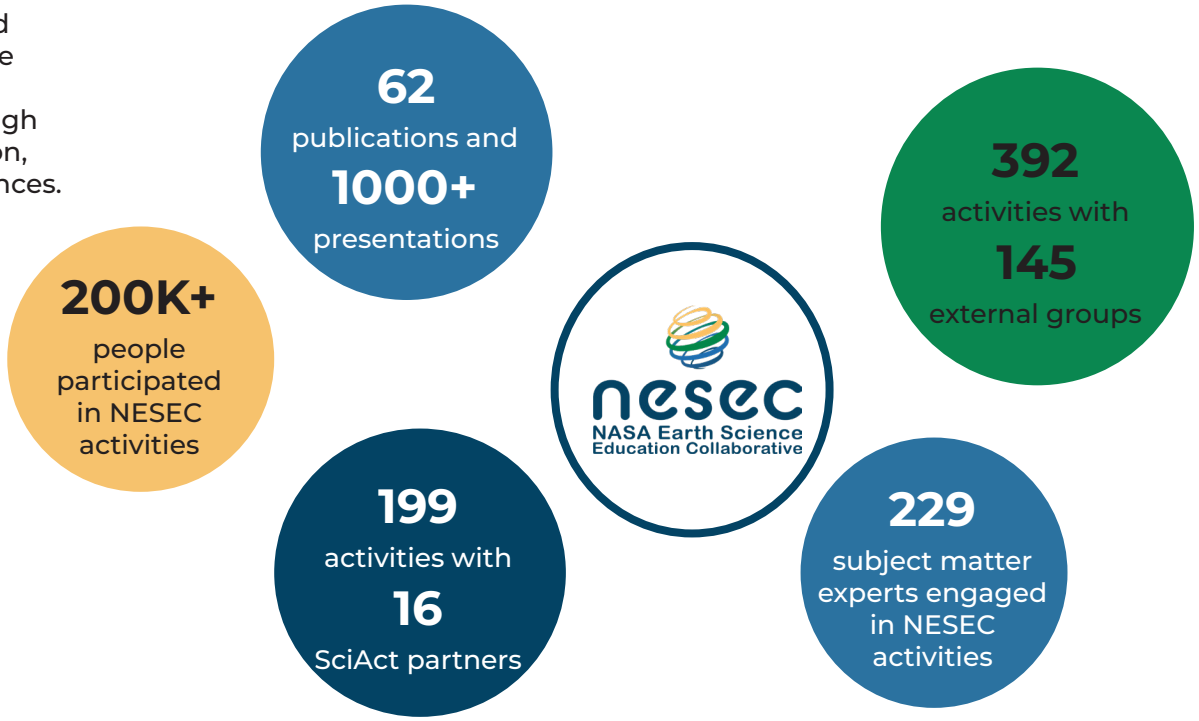
NASA Earth Science Education Collaborative (NESEC) is a NASA Science Activation project led by the Institute for Global Environmental Strategies, in partnership with NASA's Goddard Space Flight Center, Jet Propulsion Laboratory, and Langley Research Center. The project's goal is to enable broad participation in authentic NASA Earth STEM experiences for learners of all ages.

NESEC connected learners across the country to NASA Earth science by partnering with a variety of organizations to deliver authentic and participatory experiences that engaged people in the process of doing science.

This summary presents key findings from a summative evaluation conducted by the STEM Research Center at Oregon State University.

Scope and Reach

NESEC connected learners across the country to NASA Earth science through authentic, hands-on, participatory experiences.



Authentic Science Experiences

NESEC's citizen science activities engaged learners as contributors to real NASA Earth science—strengthening science identity, self-efficacy, confidence, and understanding of scientific practice across all audiences.

Adaptable and Flexible Resources for All Users

High-quality, flexible learning resources allowed partners—especially libraries and educators—to adapt NESEC programming for local contexts while maintaining scientific rigor and usability.

Working to Reach Learners Across the Country

Strategic partnerships were central to NESEC's national reach, supporting co-designed, locally relevant programming and fostering sustained collaboration across the NASA Science Activation Network and beyond.

Oregon State University
STEM Research Center

Authentic Science Experiences

NESEC provides meaningful and authentic NASA Earth science engagement nationwide. NESEC facilitated citizen science experiences through the Aviation Weather Mission with the Civil Air Patrol (CAP), internships through the Earth System Explorers program (Cho et al. 2021), and eclipse-related programming with libraries and other partners. Participants were not just learning about science—they were actively doing science. These experiences strengthened science identity, self-efficacy, skills, and confidence amongst participants.

AVIATION WEATHER MISSION WITH THE CIVIL AIR PATROL

Starting with the 2023–2024 eclipses and expanding into the Aviation Weather Mission, thousands of CAP cadets and senior members collected scientifically meaningful atmospheric and aviation-weather data using NASA's GLOBE Observer tools and field methods (Fischer et al. 2025).

IMPACTS

- **Nationwide engagement:** 3,800+ participants collected ~10,000 atmospheric and aviation-weather observations.
- **Authentic scientific practice:** Participants took cloud and contrail measurements, tracked aircraft, and recorded time-series data.
- **STEM identity and interest:** ~60% reported increased interest in science or engineering careers.

4/5

cadets reported stronger understanding of data accuracy, greater interest in science, and increased confidence in collecting data.

"A highlight from my experience was being able to work with my fellow CAP members and getting to see how we measure the data, getting to measure the data and spending time outside."

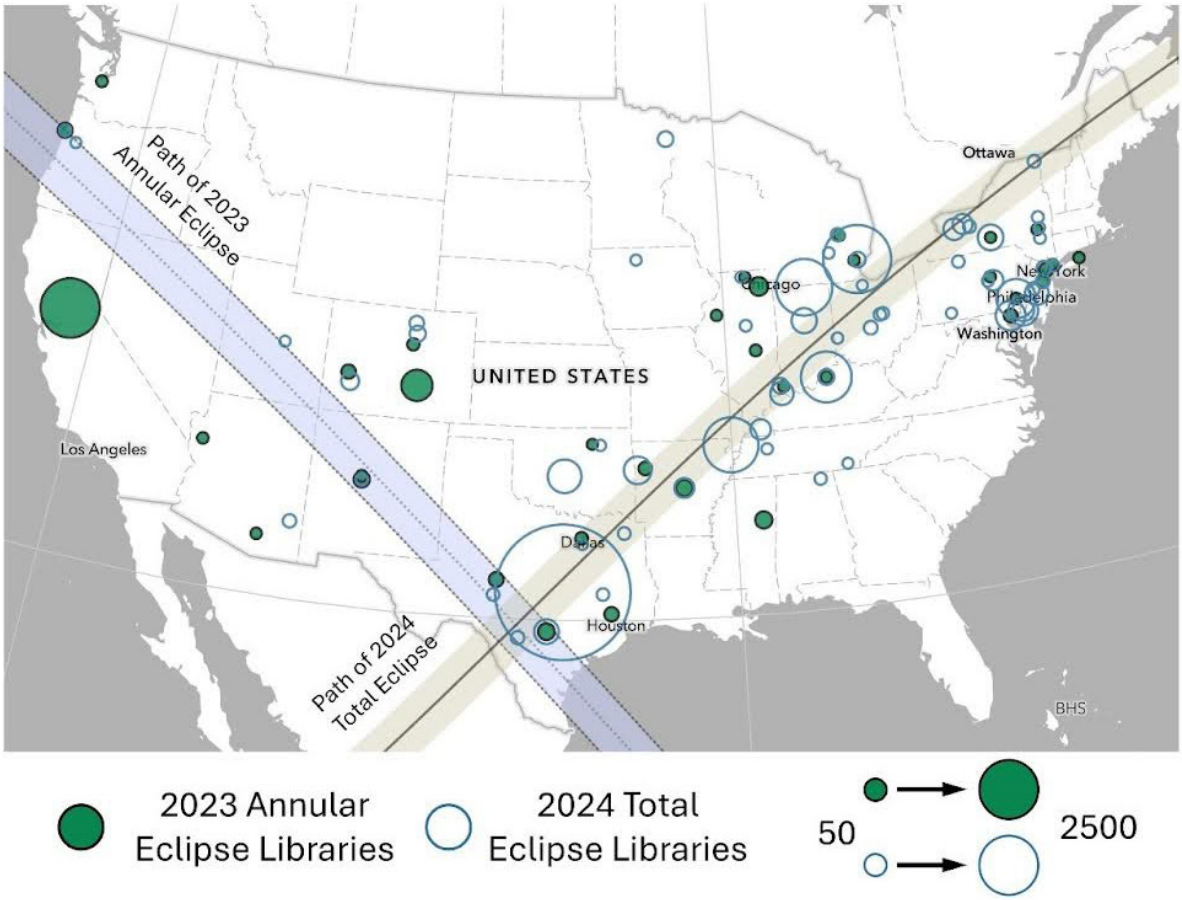
Civil Air Patrol Cadet

Adaptable and Flexible Resources for All Users

NESEC developed high-quality foundational resources designed for flexible adaptation by partners such as libraries and educators (Schwerin et al., in press; Giarratano et al., 2024). This strategy expanded reach, supported learner-centered implementation, and built long-term partner capacity.

WORKING WITH LIBRARIES TO CONNECT LEARNERS OF ALL AGES TO THE ANNULAR AND TOTAL SOLAR ECLIPSES

NESEC's multi-year library collaborations highlight the value of adaptable, high-quality resources. Using the GLOBE Observer Toolkit, Eclipse Toolkit, and multilingual, hands-on materials, libraries delivered engaging programs for children, families, teens, adults, and seniors. These resources enabled more than 150 libraries to run over 500 participatory science programs for ~40,000 people.



Location map and participant numbers for libraries' that used NESEC eclipse resources during the 2023 and 2024 eclipse events

90%

of librarians agreed the eclipse activities were simple to learn, easy to set up, and supported by effective training resources.

IMPACTS

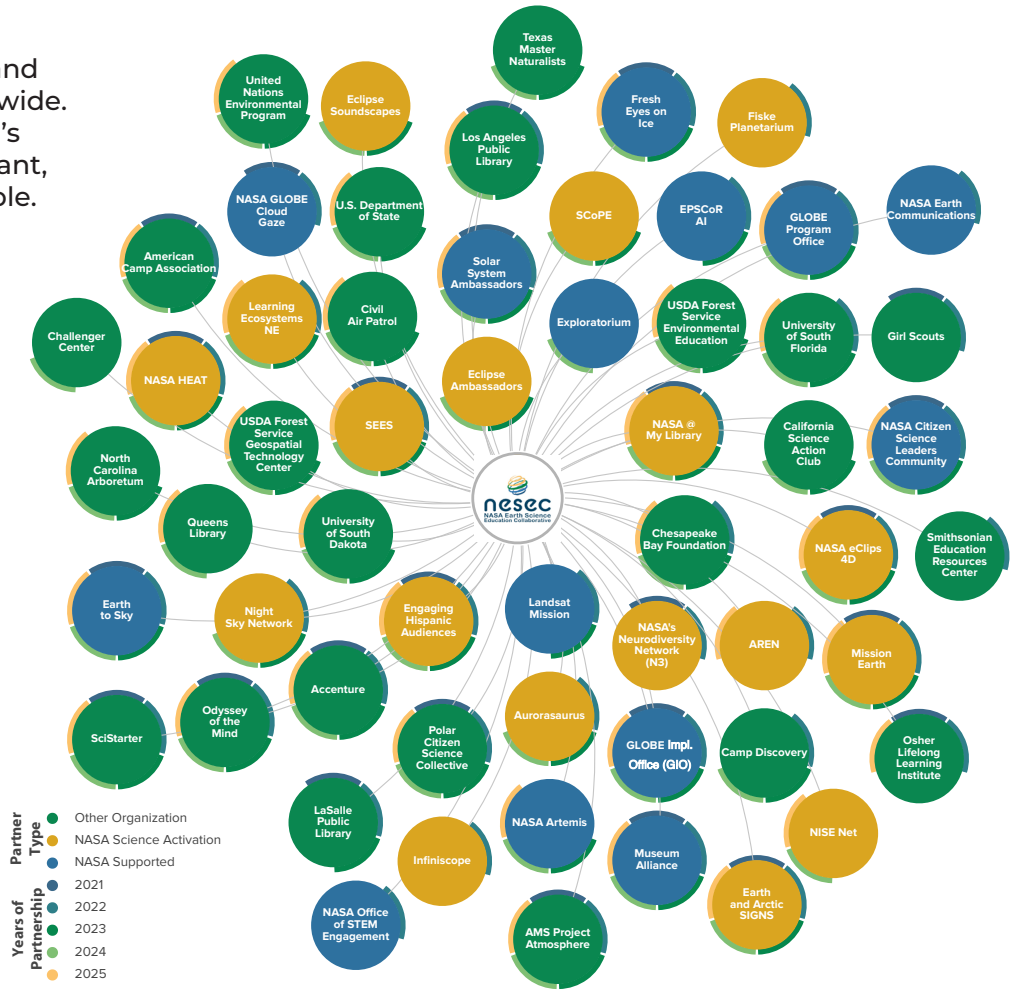
- **High-quality, adaptable materials:** Librarians appreciated the hands-on eclipse activities, clear instructions, and flexible formats of resources.
- **Support for all ages and program types:** Resources were used across different types of activities reaching audiences from young children to seniors.
- **Responsive design and continuous improvement:** Librarian input initially informed the contents of the kit and feedback following 2023 eclipse informed how we engaged libraries for the 2024 eclipse.

Working With Partners to Reach Learners Across the Country

Partnerships are central to NESEC's impact, expanding reach, strengthening quality, and connecting with learners nationwide. Partnerships ensured NESEC's programming was locally relevant, learner-centered, and accessible.

NESEC Partnership Network

Highlighting Partnerships from 2021-2025



IMPACTS

- NESEC collaborated with 22 NASA Science Activation Teams, extending NESEC's impact while adding value to partners' projects across the Science Activation Network.
- NESEC worked with 145 external groups, such as the Civil Air Patrol, libraries, and camps, to develop and deliver authentic science experiences.
- Many partners expressed strong interest in continued collaboration, and over 90% reported NESEC partnerships as effective, mutually beneficial, and aligned with their needs.

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Oregon State University STEM Research Center

nesec NASA Earth Science Education Collaborative