

Citizen Science: Local to Global
Measuring Environmental Health through Digital Images
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Overview

A national, or possibly global, network of sites for citizens to take repeatable digital photographs of the landscape and an Internet site that efficiently stores and distributes the digital images create a low-cost, sustainable, and valuable resource for both scientific environmental monitoring and formal and informal science education. A great deal can be seen and measured in photographs taken from the same location and pointed in the same direction, as illustrated in the following table:

Observed in Landscape Pictures	Value to Environmental Monitoring	Value to Education
Plants 1) Species - Type & Size 2) Leaf Cover - Amount & Color 3) Flowers & Fruit - Amount + Timing of Events	- Ground truth/verify analyses of satellite products used in research and operations - Track invasive plants - Monitor plant response to changes in local, regional, & global environmental conditions & determine important field sites - Support local to international phenology networks	- Watch & measure plant growth - Watch seasonal changes in plants and how these change over years - Expand local understandings to regional, national, and global conditions - Prepare & extend visits to parks (visit is a “snapshot” in time) - Monitor nature’s recovery from natural disasters
Land Surface 1) Type 2) Erosion	- Measure erosion rates - Measure snow depth - Measure location of glaciers	- Integrate in geography and geology activities - Relate weather, new development & landscape processes
Water Levels 1) Tides 2) River & Streams 3) Lakes, Ponds, & Puddles	- Monitor flooding response to rain events - Expand water level monitoring network	- Watch & measure flooding in response to precipitation - Compare tides at beach and nearby estuaries - Monitor shoreline changes in lakes and streams in response to weather & new development
Sky - Clouds, Sun Location, Sky Color & Visibility	- Verify cloud analyses using satellite data - Expand visibility network	- Compare what observed with satellites and what observed looking skyward - Study seasonal location of sun in the sky by monitoring shadows
Buildings/Development 1) Houses to Industry 2) Roads	- Long-term monitoring of landcover, including identifying lawn cover, using satellite imagery	- See changing landscapes due to human decisions - Monitor recovery from disasters

For over three years, PicturePosts have been in prototyping to test if the photographs and an Internet site could be used to scale up to support a national environmental monitoring effort run by citizen scientists. The following describes the PicturePost system and outlines the next steps needed to expand the network nationally.

A NASA-funded project, Measuring Vegetation Health (<http://mvh.sr.unh.edu>), provides learning activities and background materials that help people learn about plants as environmental “green canaries” and about the basics about cameras and digital images. The website provides learning activities and free software tools to manipulate digital images. The education materials support both formal and informal education, which supports the expansion of the PicturePost network. Appendix A provides details of the seven institutions collaborating on the MVH project.

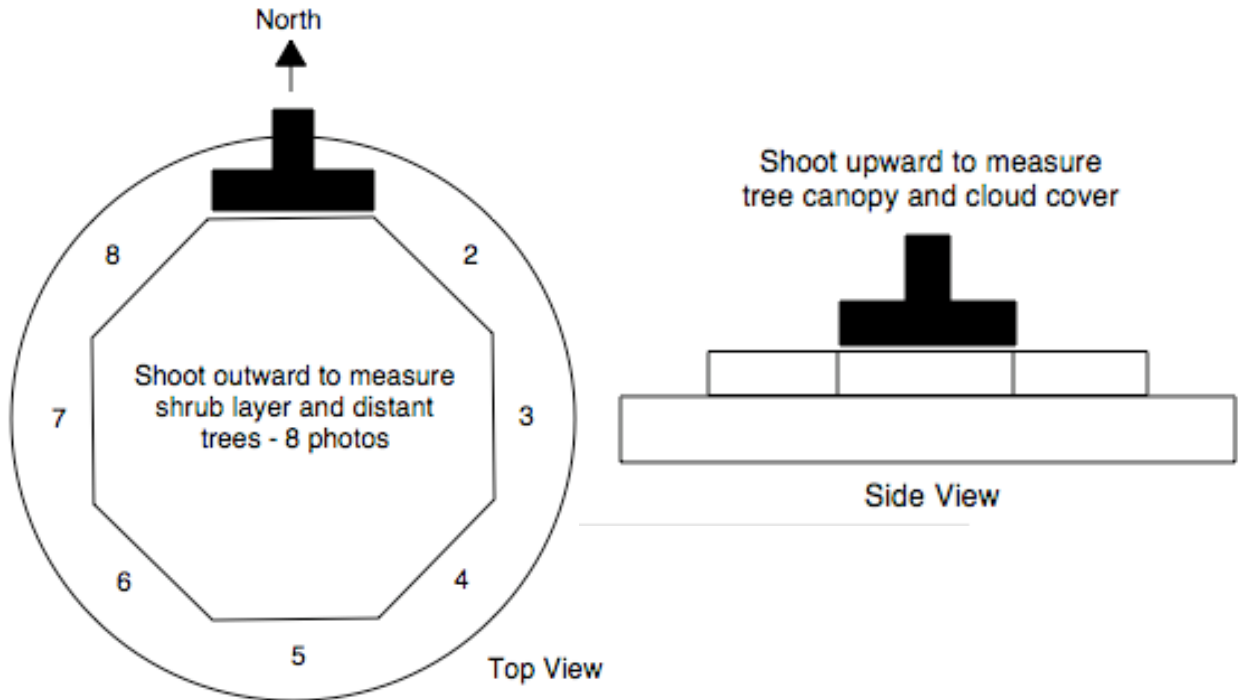
Introduction to PicturePosts

A picture is worth a thousand words – and a digital photograph provides millions of spatially organized color measurements (red, green, and blue light) that are instantly available for viewing and analysis on computers, making the images useful for a variety of needs of an Internet-connected audience. Two notable challenges exist in getting cameras outside to record the same piece of real estate in nature over time: the cost to make the camera weather- and vandal-proof and the cost and technical challenges to connect a camera outside to a computer inside. The PicturePost system eliminates both challenges by providing a low-cost, stable platform to align anyone’s digital camera to photograph the same portion of the landscape (actually, the complete 360° panorama) and a free website for people to share these photographs.

The PicturePost is simply an octagon placed in the center of a round disk and secured to a post anchored in the ground or onto a building. Using the post to position the camera, the complete landscape may be photographed in less than a minute.

Laminated instructions are posted for people to read or photograph for later reading when preparing their pictures. The post includes location name, post number, latitude, and longitude, which are useful for hikers and park visitors.





Photographs are taken with the camera placed on the disk with the back of the camera centered on an edge of the octagon. Eight pictures are taken, starting with the camera pointing north and progressing clockwise. A ninth picture is taken with the back of the camera placed on the octagon and the lens pointing skyward.

Illustrated guides about the PicturePost procedures are available at http://mvh.sr.unh.edu/mvhtools/picturepost_intro.htm.

Basics of Digital Photographs

Not all cameras were created equal – the quality and size of digital photographs range dramatically. But the data that can be collected from the variety of digital cameras is still valuable scientifically, and its value may be enhanced because a great deal of data about the camera and the photograph are stored automatically with each digital photograph. Appendix B illustrates these data that are easily available using standard software tools, such as those available at the PicturePost website (<http://picturepost.smugmug.com/>).

Additional data included with each PicturePost image: latitude and longitude of photograph and orientation of photograph. These data are included with the images by renaming the photographs and are used to sort and store the photographs when uploaded to the website.

Plants as Bioindicators

Plants are like "green canaries"— if they die, then other organisms will likely follow. By measuring the health of plants, we are measuring the environmental conditions that affect all nearby organisms, including humans. We just need to know how to examine plants to be able to read their signs of an unhealthy environment and be able to identify the causes of the problems.

Modern technologies, such as digital cameras, let us monitor plant health using the proportions of light reflected from leaves. Combining these data with our understanding and observations of plant behavior and physiology helps us to quickly assess the quality of the local environment. Photographs from PicturePosts provide valuable scientific data to monitor the environmental conditions while also providing a rich resource to help people learn about their environment. Photographing other aspects of the surrounding landscape provides additional data about the health of the environment.

Power of Citizen Science

During their research, scientists often collect relatively small amounts of high quality data that are typically limited in geographical scope. For more than a decade, citizen science efforts have been used to expand the amount and spatial coverage of scientifically valuable data. According to Rick Bonney of Cornell University, who is credited with coining the term "citizen science," the most important step in developing a successful citizen science program is to include scientists in the all stages of planning and development of the program. The PicturePost team has worked with a number of scientists in the development and prototyping stages, and is looking to expand the network of input as the next stage of expansion is being planned.

Important Next Steps

Working with the general public and educators over the past year and a half have indicated that there is a great deal of interest in creating a network of PicturePosts, but it must be an easy process for people to participate. There needs to be an affordable and easy way to acquire a low-maintenance version of the PicturePost and the process for uploading, viewing, and using the pictures must be easy to understand and easy to use. More specifically:

- 1) Create and sell pre-built, low-cost, plastic lumber version that fits on any 4 inch x 4 inch post. To purchase, see https://omega.mc.net/epsplasticlumber.com/orderform_recap.php.
- 2) Create a dedicated website for storing and distributing PicturePost photos.

One of the challenges of the current process is uploading pictures to the website, which requires the time-consuming process of renaming the photographs and uploading the pictures to separate views per PicturePost (9 views in all). The prototype website was selected because it was already operational, low cost, provided unlimited storage, and nearly unlimited bandwidth to share the photos over the Internet. The Smugmug.com uploading tools were designed for digital photographers to display and sell their photos, and so provided tools for controlling the uploading process. A website dedicated to hosting and distributing PicturePost photos needs to have:

- a) Automatic renaming of photographs placed into a folder on the photographer's computer, but with an interactive check by the photographer (the time and date of each photograph is part of the metadata automatically embedded in a digital photograph – the photographer needs to be asked if these dates and times are correct). Also, the photographer needs to be asked if the photographs are in a specific sequence – first picture taken pointing north, followed by a clockwise sequence, with the last picture taken of the sky cover. Download versions that run on Mac or PC at http://mvh.sr.unh.edu/mvhtools/picturepost_intro.htm.
 - b) Automatic uploading to the proper folders – all nine views are automatically sorted rather than the current process, which requires a separate upload to each folder.
 - c) Automatic watermarking images so the time, date, and view are visible in the images.
 - d) Photographs with a minimum focal length (included in the metadata of each digital photograph) are stitched together, creating a 360° panoramic image and stored in a separate folder.
 - e) Create easy to use search and analysis tools that efficiently use digital photograph metadata
- 3) Expand the Network of PicturePosts and Increase Number of People Contributing Photographs. Potential networks of PicturePosts may be supported by:
- a) Schools (K–16)
 - b) Parks (local, state, and national)
 - c) Science Centers (Museums, Zoos, Botanical Gardens, Arboreta)
 - d) Societies, Associations, Communities, Clubs, Organizations, and Groups involved with some aspect of the outdoors (National and State Audubon Societies, Friends of Parks, Appalachian Mountain Club, Sierra Club, Geocaching Organizations, National Garden Association, existing Citizen Science groups, such as Plant Watch (<http://www.naturewatch.ca/english/plantwatch/>), etc.)

- e) Home owners interested in watching their gardens and landscaping change
- 4) Provide feedback to active PicturePost user groups to sustain long-term interest. Feedback may be in the form of:
- a) Virtual annual meetings by way of the website
 - b) Lectures and reports by scientists to the citizen science community on how the data have been used
 - c) Photo sharathon in which users from different areas share their experiences and uses of their photographs.

Next Steps to Support Research

PictuePosts will become a valuable tool for high quality environmental monitoring when the network of posts and the number of people taking and submitting quality photographs provides a stable spatial and temporal coverage of regions. These data would be extremely useful for regional phenology alliances of scientists, schools, science centers, and community groups who would use the data to study regional issues. The importance and value of phonological measurements are detailed in Betancourt et. al. (2005).

- 1) Explore the value of enhancing digital photographs for scientific use by incorporating low-cost and available technologies:
- a) Using Plant Stress Detection Filters when taking photographs (http://mvh.sr.unh.edu/mvhtools/psd_filters.htm)

Purple Plant Stress Detection filters block green light, allowing proper exposure by the digital camera using only the available red and blue light. Healthy plants absorb generally 95% of the red and blue light illuminating the leaves; whereas, stressed plants absorb roughly 80% or less. In these photographs healthy plant leaves appear dark and stressed plant leaves appear light. It is easy to identify, locate, and measure stressed plants in these digital photographs.

Additional filters should be tested, including polarized filters.

- b) Combining Visible and Near Infrared Digital Photographs (http://mvh.sr.unh.edu/mvhtools/near_ir.htm and http://mvh.sr.unh.edu/mvhtools/equipment_sources.htm)

A useful index of plant health may be calculated using the measured intensities of red and near infrared light reflected from plant leaves. The

document, <http://mvh.sr.unh.edu/software/guides/NDVIfromDigitalCamera.pdf>, explains how to create a Normalized Difference Vegetation Index from paired visible and near infrared digital images.

c) Using Software to Enhance Spectral Analysis of Photographs (for example, see http://mvh.sr.unh.edu/mvhinvestigations/adopt_branch.htm)

The scientists on the NASA-funded Measuring Vegetation Health (MVH) project are examining the correlation between chlorophyll concentration and the spectral values of (red-blue)/(red+blue) reflected by leaves. Use the free software, MVHimage, which has this calculation? as one of the visual analysis tools (see <http://mvh.sr.unh.edu/software/software.htm> and <http://mvh.sr.unh.edu/software/mvhimage.htm>).

d) Creating an automated software tool that grabs regional coverage by specific satellite sensors at the closest time to when PicturePosts images are taken and uploaded to the website.

This will provide efficient data sets for ground truthing, or verifying, environmental measurements generated from satellite data. The data sets will be a valuable resource for education and community planning too.

2) Contact Scientists to Extend Scientific Network Using PicturePost Images

- a) Phenology
- b) Invasive Plants, Pests, and Blights
- c) Land Surface Change
- d) Air Quality
- e) Cloud Cover
- f) Ecological Forecasting
- g) Shoreline Protection

3) Align a number of PicturePosts with other data collecting systems/organizations. For example, the data measured by the Blue Hill Observatory's (www.bluehill.org) suite of atmospheric sensors may be used to extend what data can be measured from digital images? recorded by photographs taken at adjacent PicturePosts.

4) Test additional technologies used at the posts, such as sound recording. One of the benefits of the PicturePost network is that data collected is from the same known location and the time and date of the data are recorded.

This makes data collected at this network quite valuable for monitoring environmental change.

Next Steps to Support Education and Applications

PicturePost images provide visual/concrete examples that supports learning abstract Earth and Life Science processes. In particular, time series of images are useful to visualize natural and human processes at different time scales. When the images are combined with satellite imagery, the resulting sets provide recognizable images that help people understand what is being displayed in more abstract images that are taken hundreds of kilometers above the Earth's surface. USGS have created these sets with their Earthshots Landsat series (<http://earthshots.usgs.gov/tableofcontents>) and the current PicturePost website uses by integrating with Google Earth.

1) Extend the formal and informal education community using PicturePost photographs.

Education projects, such as MVH (<http://mvh.sr.unh.edu>), Forest Watch (<http://www.forestwatch.sr.unh.edu/>), and GLOBE (<http://www.globe.gov/fsl/welcome/welcomeobject.pl>), support using this type of imagery for both formal and informal education. As more educators develop activities and lessons using the imagery there needs to be an Internet repository for review and national distribution of the activities, such as the Earth Exploration Toolbook at the Digital Library for Earth System Education (<http://serc.carleton.edu/eet/>).

2) Develop business and community applications with PicturePost photographs, such as agriculture and land use and planning.

It never hurts to show that what you are learning has application in our lives.

Summary

A national network of PicturePosts supported by citizen scientists and an efficient website to efficiently archive and distribute the photographs will be a valuable resource to environmental monitoring efforts and to formal and informal education communities. After years of prototyping, a number of important next steps must be addressed to create a low-cost and sustainable PicturePost system:

- 1) Provide access to inexpensive yet durable PicturePosts to install.
- 2) Create and maintain a website that provides easy-to-use tools for people to share their PicturePost photos efficiently and for a national audience to find and use the images for their research and/or education needs.

- 3) Work with existing organizations to adopt the PicturePosts to support their research and/or education efforts.
- 4) Build long-term sustainability into the efforts.

References

Betancourt, J. L., M. D. Schwartz, D. D. Breshears, D. R. Cayan, M. D. Dettinger, D. W. Inouye, E. Post, and B. C. Reed, 2005, Implementing a U. S. National Phenology Network, *Eos*, Vol. 86, No. 51, 20, 539–541.

Appendix A: Collaborating Institutions on Measuring Vegetation Health Project

Staffs from seven institutions are incorporating their diverse talents to develop the activities, guides, resources, and information for Measuring Vegetation Health.

Museum of Science, Boston, MA (www.mos.org)

Founded in 1864 as the New England Museum of Natural History, the museum expanded to become the first to embrace all the sciences under one roof (1951). Because of its breadth of science exploration, the name changed to the Museum of Science. More than 1.6 million people visit the Museum and its more than 400 interactive exhibits each year.

Beginning in 2002, the Museum of Science expanded its mission to engage people in engineering and technology activities. The concept of Measuring Vegetation Health grew from this vision, focusing on the connection of improved scientific understanding through advancing engineering and technologies in remote sensing, communications, and image processing.

The author, John Pickle, was the original Principal Investigator for the Measuring Vegetation Health project and an employee of the Museum. He has left the Museum, and he is working with the MVH team to expand the PicturePost network.

Lawrence Hall of Science, University of California, Berkeley (<http://www.lawrencehallofscience.org/gss/>)

Lawrence Hall of Science's Global Systems Science (GSS) project provides materials including books and investigations for high school student to learn about science in the context of today's environmental issues that require thinking of the world in terms of systems. The materials can support an integrated science course or supplement traditional discipline-based courses (physics, biology, chemistry, Earth science, or social studies). Measuring Vegetation Health activities are being incorporated in the GSS books New World View, Ecosystem Change, and Ozone.

Forest Watch, University of New Hampshire (<http://www.forestwatch.sr.unh.edu/>)

Forest Watch is a New England-wide environmental education program designed to introduce both teachers and their students to field, laboratory, and satellite data analysis methods for assessing the state-of-health of local forest stands. Forest Watch provides workshops which are designed to help K-12 and post-secondary teachers introduce students to selected hands-on techniques,

based on UNH research methods, for evaluating the health of white pine (*Pinus strobus*)—a bioindicator for ground-level ozone. Through the Forest Watch program, students become actively involved in doing meaningful scientific research, and in the process, collect and compile data useful to UNH researchers in their on-going regional survey of forest health. This program was introduced in 1992 to six New Hampshire schools; it is now in the seventh year, with participating schools from New Hampshire, Maine, Vermont, Massachusetts, Connecticut, Rhode Island and Maryland.

EOS-WEBSTER, University of New Hampshire

(<http://eos-webster.sr.unh.edu/home.jsp>)

EOS-WEBSTER (a WEB based System for Terrestrial Ecosystem Research) is a digital library of Earth Science data serving the needs of both the Earth System Science community and the general public. EOS-WEBSTER was developed through a \$3.5 million dollar grant from NASA and is now supported by the University of New Hampshire's Institute for the Study of Earth, Oceans and Space. Our data holdings can be searched spatially, temporally, or by keyword, free text, or collection name. We have distributed over 150,000 data products to our users world-wide since 1999.

Indiana State University Center for Remote Sensing and Geographic Information Systems (<http://baby.indstate.edu/geo/rs/main.htm>)

Founded in 1973, the Center for Remote Sensing and Geographic Information Systems is located in the Department of Geography, Geology, and Anthropology. The Center is comprised of a research facility and a teaching facility for the applications of remote sensing and geographic information systems (GIS). Remote sensing refers to data acquired at a distance from an object and includes aerial photography, digital video data, and satellite data. GIS is a computer based information technology that is designed to manage, analyze, and display spatial data. The Center assists students and faculty with analysis and modeling of environmental problems.

Blue Hill Observatory, Milton, MA (www.bluehill.org)

Blue Hill Meteorological Observatory, located at the top of a scenic mountain range south of Boston, is a unique American institution. Founded in 1885 by Abbott Lawrence Rotch as a private scientific center for the study and measurement of the atmosphere, it was the site of many pioneering weather experiments and discoveries. The earliest kite soundings of the atmosphere in North America in the 1890s and the development of the radiosonde in the 1930s occurred at this historic site.

Today, the Observatory is a National Historic Landmark and remains committed to continuing its extensive, uninterrupted climate record with traditional methods and instruments. The recently established Science Center expands this mission by enhancing public understanding of atmospheric science.

College of Education and Human Development, University of Southern Maine (<http://www.usm.maine.edu/cehd/>)

USM's College of Education and Human Development is Maine's leading public institution for educating teachers, school administrators, and human resource professionals.

The College is firmly grounded on a rich history that dates back to the Gorham Normal School, established by the state of Maine in 1878 to educate teachers and establish teaching norms. Today, the College of Education and Human Development has a mission of preparing educators and human development professionals for responsible service that is as relevant to society today as it was more than a century ago.

Appendix B: Digital photograph metadata available on the prototype PicturePost website.

Variable	Example	Comments
Date Taken	2006-07-24 08:55:25	Essential information to track changes of landscape over time
Date Digitized	2006-07-24 08:55:25	Useful check if photograph was altered by software
Date Modified	2006-07-24 08:55:25	
Make of Camera	PENTAX Corporation	Useful in identifying quality of photographs to use in analyses
Model of Camera	PENTAX Optio W10	
Size of Photograph	2816 x 2112	Number of color measurements
Bytes	1235294	
Aperture Setting	f/3.3	Camera settings when photograph taken
ISO	64	
Focal Length	6.3mm (38mm 35mm)	
Exposure Time	0.0166s (1/60)	
JPEG Quality	normal	Provides information about artificial enhancement of the picture quality
Flash	Flash did not fire, compulsory flash mode	Natural versus artificial lighting
Exposure Bias	0	Provide information about artificial enhancement of the picture quality
Exposure Mode	0	
White Balance	auto	
Digital Zoom Ratio	100/100	100/100 indicates that digital zoom was not used
Contrast	0	Provide information about artificial enhancement of the picture quality
Saturation	0	
Sharpness	0	
Subject Distance Range	2	Distance to object focused on in meters
Color Space	sRGB	Provides information about artificial enhancement of the picture quality

For a glossary of terms, see http://www.dcresource.com/reviews/exif_key.html