Exploring Applications, Opportunities and Challenges to using Webcams for Environmental Monitoring

November 14 - 15, 2018 | Charleston, SC

SECOORA Southeast Coastal Ocean Observing Regional Association | IOOS Integrated Ocean Observing System

The *Exploring Applications, Opportunities and Challenges to using Webcams for Environmental Monitoring Workshop* was hosted November 14-15, 2018 in Charleston, SC. It brought together experts to discuss web camera data, its challenges, and the best practices for utilizing camera data for environmental monitoring.

Workshop participants shared their experiences with operating webcams, imagery data management and processing, and data analysis.

Table of Contents

Executive Summary

Web cameras are transforming how environmental monitoring is conducted. Video data is being used for applications related to transportation and commerce, preparedness and risk reduction, and stewardship of coastal resources.

The *Exploring Applications, Opportunities and Challenges to using Webcams for Environmental Monitoring Workshop* was hosted November 14-15, 2018 in Charleston, SC. It brought together experts to discuss web camera data, its challenges, and the best practices for utilizing camera data for environmental monitoring.

Workshop participants shared their experiences with operating webcams, imagery data management and processing, and data analysis.

Below are key topics that emerged from the workshop:

- Measurement vs Detection: When installing a camera, the purpose and observational requirements of the camera need to be determined. In addition to the camera view, the images can be used for detections of features/events or measurements. Data management, metadata and file formats will be similar for the two types, but additional steps need to be taken to use webcam videos or derived image products for measurement purposes.

- Web Camera Installation: To ensure data collection success, web cameras need to be installed properly. Participants discussed best practices for installing a web camera. Following are the key steps for installing a camera.

  Determine Use Case
  Identify the attributes of the coast you need to observe and determine the necessary elevation, field of view and positional characteristics (stationary or pan-tilt-zoom) of the camera to capture those attributes. Also determine if the camera data's primary purpose is for measurement or detection.

  Organized by use case themes (weather, coastal morphology / hydrodynamics, or ecological / human use), the below table identifies many potential applications that could be supported by a camera or camera network. To enable successes of use cases through a camera network, standardization and considerations of data management needs is required.

Weather	Coastal Hydrodynamics/Morphology	Ecology and Human Use
• Meteorological forecast improvement (i.e. coastal and riverine flooding, visibility, precipitation type, cloud cover, wind, severe weather detection, identification of sea or lake ice) • Situational awareness (when in real-time) • Assistance in augmenting data gaps • Post event analysis • Identifying rip currents, wave height and surf zone conditions • Human use (risk factor)	• Shoreline position • Surf zone morphology (bathymetry (quantitative) or wave breaking (qualitative)) • Beach topography (feature ID is quantitative) • Water level (wave runup, dune erosion or overwash) • Rip currents • Model applications • Longshore currents	• Provide ground truth observations (i.e. confirm or validate model predictions / forecasts; insurance claim data (example: boat speed vs wave size)) • Observations of anthropogenic use of resources including surfing, paddle boarding, and beach use • Monitor ecological services (i.e. nesting habitat (example sea turtles)) • Presence or absence detection • Growth degree for reefs and oysters • Boat traffic analysis • Potential water quality impacts (i.e. presence of wildlife, horses and/or dogs, harmful algae blooms observations) • Observations of rip currents.

Table 1: Use cases and potential applications.

Select a Host
Once a use case is determined, you need to secure a web camera host that meets the needs of your use case.

Sign an Agreement with the Host
An agreement between the operating party and host should be signed before the web camera is installed.

Select and Mount a Web Camera
Selecting a web camera and mounting it depends on your use case. Attendees discussed tips for selecting a stationary or Pan-Tilt-Zoom camera; resolution and zoom recommendations; and mounting guidelines.

Document Metadata
Metadata information needs to be developed for each camera location and attached to each video or image. This is a lesson learned from the WebCAT project and a critical step that impacts usability of video data.

- Data Management of Web Camera Data: Data management is key to ensure web camera data is never lost and meets the needs of a broad range of end users, particularly those addressing scientific questions. Data management is similar for each use case. Attendees recommended data management best practices for fields, format and storage of web camera data. See Table 4 on page 9 for more information.

- Data Analysis of Web Camera Data: Participants discussed different data analysis techniques, tools, data displays and needs plus gaps for the three use cases themes.

- Metadata – Lesson Learned: Metadata was identified as a huge limitation and lesson learned from long-time operators. Metadata information needs to be developed for each camera location and attached to each video or image. The attendees created a list of metadata recommendations.

WebCAT was funded as a one-year project by NOAA National Ocean Service and the U.S. Integrated Ocean Observing System. The workshop concluded by brainstorming next steps for the WebCAT network. Below are the steps outlined by workshop attendees.

- Perform a survey to see if users rely on the data provided by the WebCAT cameras.
- Prioritize locations and any modifications needed to meet user needs.
- Analyze existing data and maintain existing webcam data streams before growing the network.
- If funding is expended for a particular camera, cease public dissemination of the data to raise user awareness that additional funding will be needed.
- Evaluate current webpage traffic.
- Grow the network and consider aligning with Coastal Imaging Research Network (CIRN: https://coastal-imaging-research-network.github.io/#/)

This successful WebCAT project provides a foundation for establishing an operational web camera network that could address multiple needs for data and observations to validate models, perform assessments, and inform decision-making.

Overview of Web Camera Application Testbed

The workshop is a component of the NOAA National Ocean Service funded Web Camera Application Testbed (WebCAT). The project is a public-private partnership leveraging the expertise of Surfline, Inc. to install and operate several web cameras to meet the needs of a diverse group of federal and academic users. WebCAT seeks to facilitate and standardize the collection of coastal webcam imagery to maximize data access and to show the benefits of web cameras for different end use applications. In the long-term, the WebCAT project lays the groundwork for a potential future nationwide webcam coastal ocean observing network.

Thank You

This workshop would not be possible without the help of the Meeting Planning Committee members and funding from the Integrated Ocean Observing System (IOOS) and NOAA NOS. A special thank you to Chrissa Waite and Bethney Ward for volunteering their time and facilitating the successful and productive workshop.

Melinda Bailey, NOAA NWS
Kimberly Bailey, NOAA NWS
Jenna Brown, USGS
Marie Bundy, NOAA-OCM
Michael Churma, NOAA NWS
Greg Dusek, NOAA NOS
Debra Hernandez, SECOORA
John Kuhn, NOAA NWS
Joseph Long, UNCW (formerly USGS)
Dennis Murphy, Surfline
Dwayne Porter, USC / NERRS
Tiffany Vance, NOAA IOOS
Chrissa Waite, NOAA OCM (facilitator)
Abbey Wakely, SECOORA
Bethney Ward, USACE (facilitator)
Kyle Wilcox, Axiom Data Science
Mark Willis, NOAA NWS (formerly Surfline)

WebCAT Project Background and Limitations

Time was spent reflecting on the successes and issues posed during the WebCAT project. Documenting this information is beneficial to laying the groundwork for a potential future nationwide web camera coastal ocean observing network. Below is a summary of the discussion.

Camera Location	Stationary or Panning	Surveyed (Y/N)	Elevation above ground (m)	Primary Use Case	Other Potential Uses	Limitations
Buxton, NC	Stationary	Y	10	Wave runup	• Weather observations • Run down extent • Dune erosion	• Elevation is not sufficient for surf zone monitoring (e.g. rip currents) • Due to low elevation, multiple cameras could be useful to extend cross-shore and alongshore field-of-view.
North Myrtle Beach, SC	Stationary	N	15	Beach use and water quality; rip currents	• Weather observations	• Not discussed at the workshop
Folly Beach, SC – North	Stationary	N	15	General monitoring	• Recreational viewing • Weather observations • Beach use vs. contaminants	• Not discussed at the workshop
Folly Beach, SC – South	Panning	N	15	General monitoring	• Recreational viewing • Weather observations	• Panning hinders quantitative measurement (e.g. shoreline) • Details of the panning (orientation, etc.) not included in metadata
St. Augustine, FL	Panning	N	10	Whale monitoring	• Weather observations	• Not discussed at the workshop
Miami, FL	Stationary	Y	40	Rip currents; wave runup	• Weather observations • Beach use	• Repeated power and internet issues (lightning and construction); requires survey efforts to be repeated • Beach is too populated to look at wave run up signal
Bradenton, FL	Stationary	N	5	Rip currents	• Harmful Algal Boom detection • Weather observations • Shoreline	• Obstruction (palm leaf) blocked camera view • Elevation is not sufficient for surf zone monitoring (e.g. rip currents) • Limited cross-shore extent, cannot see full runup signal or dune erosion.

Table 2: Reflections by camera.

Measurement vs. Detection

When installing a camera, the purpose of the camera needs to be determined. It can be used to make detections (e.g. presence of rip currents, presence of whales, etc.) or, if surveyed and calibrated, it can be used to make quantitative measurements (e.g. speed of rip currents, extent of wave runup, etc.). Data management, metadata and file formats will be similar for the two uses, but additional steps need to be taken for measurement purposes.

Measurement
Measurement is using the web camera for observing features in real world coordinates and making quantitative measurements, such as studies conducting time series analysis of wave runup or changes in shoreline position. Web cameras for measurement are usually positioned higher and are stationary; if the camera is panning, the updated camera positions need to be accurately documented.

Extra steps need to be taken when using the web camera data for measurements in order to account for lens distortion and to relate image coordinates to real world coordinates. In addition, the exact location of the camera needs to be made available. A series of photos of a checkerboard pattern of known dimensions is collected to solve for lens distortion parameters (also known as camera “intrinsics” or “interior parameters”). The position of a number of ground control points in the camera field of view and in world coordinates, along with the position of the camera itself, are used to determine the camera position and orientation (also known as camera “extrinsics” or “exterior parameters”). A number of these parameters should be included in the metadata if available. Additionally, regular (e.g. quarterly, annually, post-storm events) morphological surveys of the camera field of view should be conducted to accurately relate 2D image coordinates to 3D world coordinates in the entire image.

Detection
Detection is using the camera to count features or observe trends, such as identifying rip currents or populations or confirming weather observations. Basic metadata needs to be taken once the camera is installed. The web camera is sometimes positioned lower (or in some cases a higher camera is preferred for rip currents). Calibration is recommended but not necessary for detection purposes. Cameras used for detection can often be “cameras of opportunity” or pre-existing camera installations, as the position, orientation and movement characteristics (stationary or pan-tilt-zoom) is not as critical as with cameras used for measurements.

Best Practices on Web Camera Installation

Camera installation was discussed at the workshop. Below are installation best practices developed by workshop attendees.

Step 1: Determine Use Case

Determining the web camera use case is the first step to installing a web camera. Identify the feature(s) to be observed and if the camera data’s primary purpose is for measurement or detection. The use case determines camera specifics and host requirements. Some questions to answer are:

- What field of view is needed to meet the requirements of the use case?
- What vantage point is needed?
- Is the camera intended to stream imagery in real time or will the video footage be recovered later?
- Will the camera be stationary or pan-tilt-zoom? If the latter, how and when will the camera change position?
- Will the placement of the camera require anything special like a wireless link or electrical work?
- Is the use case for measurement or detection?

Step 2: Select a Host

Once a use case is determined, you need to secure a web camera host that meets the needs of your use case. You should ensure the property has reliable internet and power, and is easily accessible. The elevation should also be sufficient to observe the required features.

You are essentially renting a small space on the hosts property. To solicit a host, you can approach them directly, advertise that you are searching for a host, or (in an ideal scenario) they can approach you. Condos and properties with Homeowners Associations can be difficult. It might be necessary to reach out to multiple potential hosts before one is willing to install a web camera on their property.

Tip
Public endorsement is beneficial for securing a host. If working to answer a science question, you can give presentations at town meetings on the project, showcasing what the data is being used for. This will result in endorsements from the community. An example was given of a nourishment project soliciting Letters of Support and sharing them with the condo associations when they approached to install a web camera on their property. They also had a FAQs sheet on the project.

Step 3: Sign an Agreement with the Host

An agreement between the operating party and host should be signed before the web camera is installed. It is recommended to stay away from informal (verbal) agreements. It outlines the requirements of each party, the basic use of the camera, and exclusivity. The agreement should outline the:

- Responsibility for power and internet costs
- Agreed internet usage
- Maintenance schedule
- Accessibility
- Liability
- Data usage
- Length of agreement (identify if it will it auto renew)
- Certificate of insurance
- Exit strategy

After an agreement is signed, it is important to check back in and communicate with the host to show how you are adding value.

Step 4: Select and Mount a Web Camera

Selecting a web camera depends on your use case. Below are some specifications to consider.

Stationary or Pan-Tilt-Zoom

You should determine if you need a pan-tilt-zoom (PTZ) or stationary camera.

Pan-Tilt-Zoom (PTZ)	This camera can be best for detection use cases. It can be used for weather observations, security, media, entertainment and qualitative extreme event observations. A PTZ camera can be controlled remotely to focus on ephemeral features, have reduced maintenance costs (fewer onsite visits for adjustments), and it can lock down on a single preset or you can set multiple presets with different duration. A single camera with PTZ can also increase the field of view without additional cameras. In some cases, the camera installed might have PTZ functionality, but can be held stationary. PTZ cameras do have higher upfront cost and are more difficult to install.
Stationary	This type of camera is best for measurement use cases. It should be used for any use case that requires time or spatial series of geophysical variables. These cameras provide data that can used for numerical model verification including processes like wave runup, and shoreline change. Stationary cameras are lower cost and have faster installation times. Stationary installations only have one view, so an onsite visit is needed for any adjustment and multiple cameras are needed to increase the field of view.

Table 3: Stationary or pan-tilt-zoom summary.

Resolution and Zoom

Determine the use case to define the necessary resolution of the camera. Higher spatial resolution is needed for looking at foam, currents and waves. Low resolution is adequate if you need to observe contrast, like identifying the shoreline. Zoom of the camera is important to ensure you are looking at what you need to. It is best to overshoot the field of view.

Mounting Camera

There are many ways to mount a camera: wall, parapet, flat roof top, pole, or a custom installment. Be sure to consider the field of view needed when selecting mounting height. Cameras mounted high are ideal for most measurements use cases (wave runup, morphology, etc). Cameras mounted low are better for some detections use cases (counting people, surfers, identifying objects, etc.). In addition, consider the orientation of the camera. Be sure if looking outward, the sun does not overexpose the image.

Strengthening of camera installation locations can help reduce downtime (such as hurricane hardening).

Step 5: Document Metadata

Metadata information needs to be developed for each camera location and attached to each video or image. Do not skip this step! See section “metadata” on page 11 for more information on documentation and lessons learned from the WebCAT project.

Data Management of Web Camera Data

Data management of web camera data is key to ensure web camera data is preserved and that it is available to meet the needs of users addressing various science questions. Attendees separated into working groups to identify data management by each use case. Results show that significant overlap in data management issues exists between use cases.

Below is a summary table of data management recommendations. Metadata needs to be considered when setting up data management processes for web camera data.

Data Fields	Data Format	Data Transmission and Storage	Camera Calibration	Data Management Needs and Gaps
Time (GMT), date range, and location (latitude/longitude) Owner/host contact info Camera Model #, elevation, mount type, and power source Frame rate Heading, pitch, roll Brightness, aperture, and color/RGB Field of view, resolution and distortion	Still photos (JPG) or video (mp4/ H.264) Raw images or processes image products NetCDF (Network Common Data Form) for derived products and pixel stacks (i.e. time series of a pixel)	Data transmission via satellite, cellular, hardwired network, or local storage with periodic manual download (SD card) Local, cloud, or archive storage Required public vs private access Required ease/speed of data access Consider uploading images or video packets at certain (non-peak) times Only portions of the data may be necessary to retain Processed products that could/should also be retained Could consider turning camera off when not in use.	Intrinsic and extrinsic camera calibrations needed for measurement use cases	Standard nomenclature across use cases Training, expertise, and standardization in analyzing and storing data

Table 4 Summary table of data management recommendations.

Data Analysis of Web Camera Data

Once the purpose of the camera is determined (measurement or detection), the camera is installed, metadata is developed, and data management is in place – it is time to analyze camera data.

For each use case, participants discussed analysis technique(s), tools, data displays and needs and gaps.

Below is a table summary.

Figure 1: Attendees in breakout groups discussing data management and data analysis needs.

Use Case	Existing Analysis Tools/Techniques (*free software)	Useful Data Products	Data Displays	Needs + Gaps of Data Analysis
Coastal Morphology / Hydrodynamics	CIRN (Coastal Imaging Research Network) Stream 7 (Image Collection)	Time average and variance Georectified images/products Detected features (e.g., shorelines) Bathymetry / topography Pixel time series (e.g., for water levels, wave height, wave runup)	Combine ideas from current displays: • USGS: https://coastal.er.usgs.gov/hurricanes/research/video-remote-sensing.php • Argus: http://cil-www.coas.oregonstate.edu/ • WebCat: https://secoora.org/webcat/ Include georectified image products	Robust, automated feature detection Calibration data QA/QC procedures Archive images Easily accessible tools Documentation standardization Well-documented user requirements
Weather	Visual observation by forecasters	Observations/detection of precipitation, visibility, rip currents (help validate forecast & train machine learning)	Combined multi camera views (situational awareness display) Tagged images / features Qualitative metrics (e.g., crowded beach) Decision support (e.g., life guards)	Automated weather alert systems Identify priority sites for more cameras Training datasets for machine learning Central place to access all camera data
Ecological and Human Use	R TensorFlow (https://www.tensorflow.org/) iSpy Amazon Rekognition (https://aws.amazon.com/rekognition/) Photoshop *GIMP	Detection of people / animals Position and velocity of objects	Derived detections of position/velocity Summary products showing patterns over time Educational displays of animal behavior change	Github repository for tools (see CIRN Github) Tutorials for auto-tagging tools

Table 5: Summary of analysis technique(s), tools, data displays and needs plus gaps.

Needs, Solutions, Challenges and Gaps

Workshop attendees spent time identifying needs, gaps, challenges and solutions for the WebCAT network and web camera data collection in general.

WebCAT Network Challenges

Making Camera Coordinates Available
Hosts do not like their location broadcasted and there could be vandalism issues. However, to perform analysis on the WebCAT imagery, scientists need exact locations. One idea was to implement a registration system for researchers to gain access to camera location coordinates.

This could restrict public access, and record who has the camera coordinates. In addition, this could be an opportunity to survey how they will be applying the data.

Personnel to Maintain and Calibrate Web Cameras
When a web camera is unexpectedly moved or replaced due to damage, it needs to be recalibrated and resurveyed. One recommendation was to train local partners to maintain the camera and perform the calibrations.

Metadata – Lessons Learned

Lack of metadata was identified as a significant limitation. Metadata information needs to be developed for each camera location and attached to each video or image.

Below are recommendations on metadata needed for all video files.

Video or image specific information

- The start time of the video
- Frame rate or sample rate (e.g. 30 frames per second)
- Timestamp associated with each specific frame
- Information regarding any missing frames

Camera specific information

- The make, model and firmware
- Lens type and information
- Identify if the camera was surveyed (or not). If surveyed, provide survey date and results
- If stationary or PTZ camera
- The orientation of the camera (e.g. from the horizontal and along the beach) and the orientation of each PTZ position if not stationary
- The time associated with each PTZ position if not stationary
- Maintenance history (i.e., if/when camera was physically moved, if/when camera hardware was changed)

Location specific information

- Latitude, Longitude
- Elevation
- Location descriptor (e.g. camera is on a certain building facing X)
- Site description (e.g. how much beach, water, sky)

In addition to these initial recommendations there will be a comparison with present Argus metadata fields to ensure some consistency and that all necessary fields are included in webcam data. Other federal imagery data will be assessed to ensure consistency with any standards generally accepted across NOAA and other federal agencies.

Challenges for Broad Usage of Web Camera Data

Participants spent time brainstorming solutions for gaps that prevent the application of webcam data or needs that improve webcam data use for environmental monitoring applications.

Need or Gap	Solution
Co-locate raw image and metadata	• Metadata in Mp4 views • Computer science / data management expertise
Increased Spatial Coverage	• Engage other webcam operators (DOT, News, etc.) • Information for other groups to setup their own • SECOORA providing portal for dissemination (encouraging more people to put up cameras)
Standard metadata nomenclature and standard structure	• Metadata team or working group (Surfline, CIRN, SECOORA)
Funding to maintain WebCAT Network	• Apply new use access • IOOS • NOPP • Identify agency interests for collaboration • Student competitions • Potential NOS or NWS funding
Ongoing Community of Practice	• Regular meeting tied to conferences
Quality Assured and Quality Controlled (QA / QC)	• QARTOD style documentation (based off community best practices) • One group to determine what to include • Need to QA / QC data and processing code (solution: standard code repositories with regression testing and good version control)
Archive of images / central place to access	• Shared to google drive folder • IOOS Repository (similar to SECOORAs) • Publicly accessible • Digital coast • IOOS portal • Axiom research workspace
Funding to Analyze	• NOPP funding opportunities • Identify / fund basic questions using camera data • Identify agency interest for collaboration
Automate weather alerts	• Research and Development (algorithm for analysis) • Helios camera viewer • Identify high risk weather events and their optical software
Where are more cams needed	• IOOS coordinate efforts with multiple stakeholders to identify locations • Frequently studied sites • Sites at risk (hurricanes = potential for money) • Co-located with other measurements to develop training data sets and then look at usage forecasts via google analytics • Locations of high impact to public safety or commerce, but with no leverage from another observing platform
Github / Wiki / Slack for code sharing	• Dedicated funding and time • Expand CIRN to make it not just ARGUS focused • NOAA VLab
Tutorials for Using Software	• Jupyter notebooks • Put tutorials on WebCAT webpage (or at link videos) • Bootcamps • Youtube videos
Learning groups for software / analysis	• Online video lessons • Computer science machine learning conferences • Bootcamps / workshops
Tools to tag images for machine learning	• Zooniverse.org (citizen science) • Image net • Dave Clarks group discussion • Naval research lab • Haml (HTML Abstraction Markup Language
Well documented user requirements	• Ask for new users for pain points in process • Regional user assessments • Outreach workshops
Robust, automated processes	• Look at other fields (self-driving cars, etc).

Table 6: Challenges for web camera data and identified solutions.

Next Steps for WebCAT

WebCAT was funded as a one-year project by NOAA NOS. The workshop concluded by brainstorming next steps for the WebCAT network. Below are the steps outlined by workshop attendees.

- Perform a survey to see if users rely on the data provided by the WebCAT cameras.
- Prioritize locations and any modifications needed to meet user needs.
- Analyze existing data and maintain existing webcam data streams before growing the network.
- Consider blocking public access to the webcams to raise awareness of the need for funding
- Evaluate current webpage traffic.
- Grow the network and consider aligning with Coastal Imaging Research Network (CIRN.

Appendix 1: Summary of Presentations

WebCAT Overview

Introduction to Web Camera Application Test Bed (WebCAT)

Greg Dusek, NOAA National Ocean Service | PDF of slides

Greg Dusek overviewed the WebCAT project. He made the parallel of High Frequency Radar (HFR) and web cameras. In early 2000, the HFR community came together to standardized practices for HFR operations. This includes national standards for data collection, quality control of data and creating storage at a centralized repository. This is similar to the web camera community.

The goal of WebCAT is to develop a sustained operational webcam network with standardized imagery data acquisition and processing for a range of downstream applications. Currently, there are no standardized practices for web cameras outside of Argus. Standardization promotes innovation.

The WebCAT project was initiated as a funded NOAA National Ocean Service (NOS) stimulus project in late 2017. It is a unique private-public partnership involving SECOORA, NOS, National Weather Service, Surfline, USGS, Axiom, and academia. The project had funding for five cameras but ended up with seven thanks to Surfline. Surfline capitalized on the project and installed their own cameras in co-location with a few WebCAT cameras because they knew their customers would also be interested in the data as well. ‘

Majority of the cameras have been active since February 2018. The system includes cameras that are HD Pan Tilt Zoom cameras – at 30 frames per second, 1280x720 resolution. There have been issues with the Miami camera going down due to lightning or other factors. Surfline repaired the Miami camera outside of WebCAT budget because they are required to share the data with their customers.

WebCAT has many uses. Below are examples how WebCAT partners are using the data:

- Coastal Morphological change
- Hydrodynamics
- Human Impact on coastal resources
- Ecology, environmental and water quality
- Recreation and weather observations

Greg ended his presentation with a few questions (below) on the future of the WebCAT project. Discussion on these questions will happen throughout the workshop.

- How do we sustain and increase observations?
- How to do we develop and ensure standardized data collection, processing, metadata, quality control, access?
- Can we continue to progress image analysis and applications?

WebCAT Tools and Data Management

Dave Foster, Axiom Data Science | PDF of Slides

Dave Foster provided an overview of Axiom Data Science. They are the data management partner for SECOORA. Axiom's is mission driven. They want to build capabilities which accelerate the synthesis and re-use of earth science data.

Axiom developed the WebCAT tool for visualizing and downloading the data (www.secoora.org/webcat). The WebCAT tool provides an interactive web page to browse both live feeds and historical archive footage from a number of webcams set up at fixed locations. The historical archive video clips are broken into 10 minute segments and cover 5 AM through 10 PM each day. The clips are in 1280×720 resolution, encoded with the H.264 codec, and are approximately 110mb each.

The WebCAT tool shows the real time camera data, but for viewing or downloading archived data (historical clips) there is a 2-day delay. This is so it does not interfere with Surfline premium membership.

Axiom recognizes the need for metadata for each camera. They have worked on a WebCAT Archive Footage Availability chart to show when the cameras were down (see here).

This is an HTML page and very easy to update. Axiom has the capability to do post processing based on your needs.

Current Applications

Outcome: Participants will receive an overview from experts in the field on the current inventory of current coastal environmental monitoring (operational and research) use cases for webcam footage.

Coastal Imaging of Morphology

Katherine Brodie, U.S. Army Engineer Research & Development Center | *PDF of Presentation*

Katherine Brodie provided a brief history and overview of ground based coastal imaging. In the 1980s Oregon State University automated the use of video cameras to measure coastal processes. From the 1990s-2000s, this automated data product grew to the global Argus network. The Argus system is a long term, low cost coastal monitoring tool to allow better understanding of how the beach and nearshore react to and influence wave and tidal forcing.

Katherine Brodie then reviewed the basics of photogrammetry. With a few pieces of information, scientists can exploit how a camera lens works to make quantitative measurements within the camera field of view.

oblique images are taken from a high point angled as a slope and then projected / georectified to make spatial measurements. Image projection uses intrinsics (lens distortion measurements) and extrinsics (orientation and position measurements) in combination with known topography to rectify the image into map space.

Camera "intrinsics" or "interior parameters" are taken to calibrate lens distortion. A simple calibration is needed to determine distortion coefficients to remove the lens effects. Taking pictures of objects of known size (like a checkerboard) allows scientists to solve the distortion coefficients. The wider the field-of-view, the more distorted the imagery and the more spatial variability in the ground sample distance.

Camera “extrinsics” or “exterior parameters” is known as the position and orientation of the camera. The position (X, Y, Z) of camera needs to documented, along with the orientation (heading, roll and pitch). This can be difficult to measure. Scientists use Ground Control Points (GCP)s and survey the location to solve for position and orientation. This step is critical to making maps with your images. There needs to be at least four known features (or Ground Control Points) in the field of view. Ground Control Points must have a good distribution in the field of view. This step needs to be redone every time the camera moves or a correction algorithm needs to be applied to match features between images to remove movement.

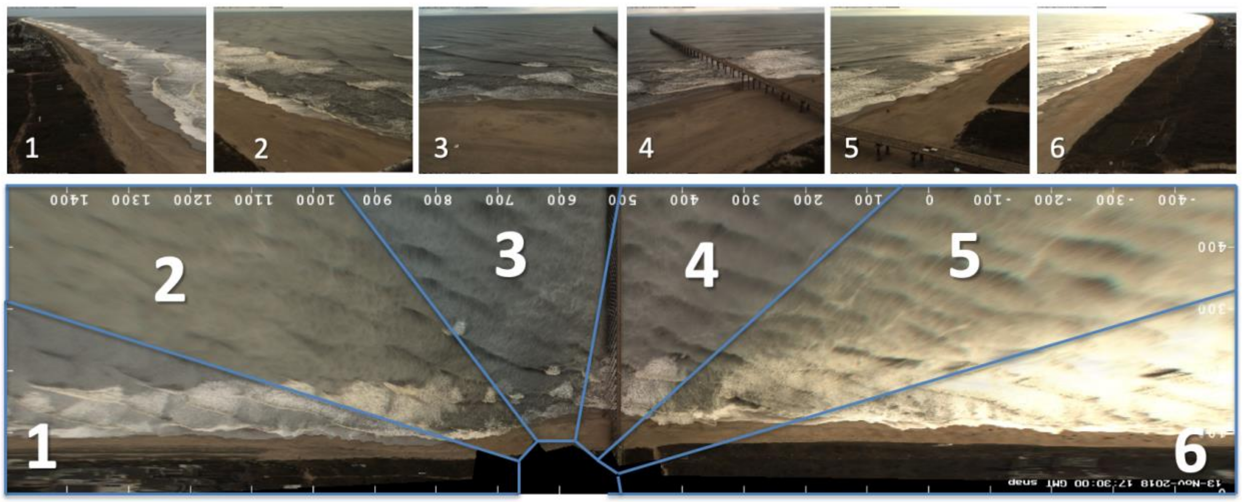

Image projection uses intrinsics (lens distortion measurements) and extrinsics (orientation and position measurements) in combination with known topography to rectify the image into map space (see above).

In coastal environments, it is hard to know the topography because is changes so quickly. Some suggestions are to: use tide elevation as water elevation; use idealized beach profile as topography, and update topography when new surveys are completed (e.g. lidar data). This will introduce error in relative measurements, but error is less important the higher your camera is located and is looking close to straight down.

There are different types of images are collected to measure coastal morphology. Time-average photos can be used for wave breaking locations. Brightest photos can be used for shoreline inundation (runup), set breakpoint locations, and tracking bright objects such as birds. Darkest photos can be used to for tracking dark objects (people on beach or wildlife) and wave shoaling region. Variance photos highlights regions that change frequently.

Example applications were provided for using cameras for coastal morphology.

- Maximum Runup Position: Brightest image can quantify how often runup reaches a certain position on the beach and identify average dry beach width (important for dune building).

- Beach Nourishment Evolution: It can show the building and evolution of the different Beach Nourishment projects.
- Rip Currents: Persistent areas of no wave breaking can be associated with rip currents.
- Hydrodynamics: By doing time-series analysis on videos, it can quantify current magnitudes and directions from tracking foam, wave runup spectra, and wave breaking percentage.
- Bathymetry: spectral analysis techniques can be used to measure the speed of waves, and from that it can calculate wave speed calculate water depth. Accuracy is dependent on wave conditions (less breaking = more accurate).

The Coastal Imaging Research Network (CIRN) was overviewed. CIRN is an international group of researchers who exploit visible signatures of phenomena in coastal, estuarine, and riverine environments. CIRN members develop new methodologies to gain a better fundamental understanding of the processes shaping those environments from imagery. The have a GitHub page with free resources and code that is open to the public (this includes a cBathy User Manual that provides information on how to estimate bathymetry).

Hydrodynamics/Rip Currents

Greg Dusek, NOAA National Ocean Service | PDF of Presentation

Rip currents are relatively narrow offshore directed jets of water that begin in the surf zone. There is an estimated over 100 drownings in the U.S. each year. NOAA National Weather Service has developed a rip current forecasting modeling known as the Nearshore Wave Prediction System. The model will hopefully be operational next year. Currently, lifeguard observations have been used to for model validation.

The rip current model has limitations. Observations for validation and calibration are inadequate. The model has no inclusion of surf zone bathymetry. In situ measurements are hard to collect in surf zone.

Web cameras can be used to visually spot rip currents and assist in validating the model. Using imagery for rip current identification can be a simple approach (identify rip currents in time average imagery) or a complex approach (Particle Image Velocimetry to observe flow magnitude). Scientists can use imagery to track where rip currents are breaking and where they are not.

Using imagery for surf zone bathymetry model inputs can be a simple approach (qualitative estimates of bar uniformity from average imagery) or a complex approach (use cBathy for quantitative estimates of surf zone bathymetry).

A few years ago, SECOORA funded a study in South Carolina to use imagery to validate the rip current model. Temporary webcams and ADCPs were installed at the study site. Challenges arose where the full video data was not retained, and wave conditions did not cooperate during the field study time. To identify rip currents, a person manually went through the data and could be misidentifying the data.

Using the Miami web camera data, they began to analyze the modeled data over the collected imagery. They modeled the likelihood of a rip current with a red light stop graphic and ran that model along with the time series of the imagery data collected. It has shown when there is high likelihood of a rip current (red dot) there was lots of wave energy in the surf zone. The team will continue to explore WebCAT imagery and compare Miami imagery data to lifeguard observations.

Operational Weather Forecasting Hydrodynamics/Human Use

Ben Freeston,Surfline | PDF of Presentation

The team at Surfline / Wavetrak developed a technology to detect objects and track their movement in real time using web camera data. This technology works by using existing object detection networks and retraining them with large sets of labelled data. It then uses multi-class to separate objects by state (sitting surfer vs paddling surfer) and an algorithm is applied to track the objects movement. See PDF of Presentation for details.

Operational Weather Forecasting

Steve Rowley, Science Operations Officer at National Weather Service Charleston | PDF of Presentation

Web cameras are used by National Weather Service (NWS) forecasters every day. They are critical to operations and have been incorporated into the forecast process. NWS Forecasters utilize coastal webcams to:

- Observe current marine and surf zone conditions (this includes cloud cover, current weather, wave conditions, crowd levels and aiding in rip current forecasting);
- Fill the gap and augment for lack of satellite, radar and surface observations, both spatially and temporally;
- Verify radar trends (for example if a forecasters observe a shelf cloud, winds are likely greater than 35 knots); and
- Verify warnings such as waterspouts, hail, high winds, and wind damage.

In addition, web cameras can aid Decision Support Services. They can assist in smoke management along the coast (confirming Dense Smoke Advisories for land and water), port operations (viewing sea fog) and the assist in forecasting events.

Web Camera Data is incorporated in NWS Weather Forecaster Offices operations area through the Situational Awareness Displays (SAD). A local software grabs static images from area webcams and incorporates image loops into SAD for viewing by all personnel in operations. Use of loops increase situational awareness and gives forecasters better a look at current coastal trends (lowering visibilities, increasing swell, etc). All images archived for post-event analysis.

The challenge with web cameras are constantly changing. It is difficult to maintain URLs. Security protocols can sometimes prevent proper viewing or completely block access. SAD is constantly pinging websites, and this can sometimes block users because they access the cams too frequently.

State of Knowledge on the Use of Webcams for Ecological Applications

Dwayne Porter, University of South Carolina Arnold School of Public Health | PDF of Presentation

After a literature research, there was not much information available on the use of web cameras for ecological applications. While the use of remote sensing technologies to address ecological applications are extensive and diverse, the use of web cameras is currently limited.

Ecological applications seem to be qualitative, "for enjoyment," viewing. For example, the National Park Service maintains a series of webcams providing real-time views of the parks. A number of National Estuarine Research Reserve System (NERRS) maintain web cameras for viewing wildlife, tidal stages, vegetation, etc.

On ecological application that were quantitative was quantitative was Phenocamnetwork. It is a network of webcams with automated image processing to remotely quantify the phenology of plant communities. If you install an appropriate camera and connect it to the web, the network will do all the image analysis, data processing, data-hosting, etc.

Examples of ecological research-projects included:

- Quantifying changes in forested extent for an alpine tree line ecotone
- Monitoring fall leaf color changes
- Calculating normalized snow indices
- Tracking invasive species
- Bacterial source tracking
- Assessing impacts of boat wake on marsh slumping
- Monitoring fish passage

There are also ongoing research efforts to assess the use of web cameras for water quality conditions including Harmful Algal Bloom formation and Counting / tracking things in the water.

Some considerations for web camera set up were listed:

- Type of communication to camera either hard-wired (best case scenario) or via wireless, radio, etc.
- Bandwidth limitations and associated loss/gain of resolution
- Location of camera and associated logistics of servicing
- Power
- Vandalism

It is noted capturing and then posting unwanted / inappropriate imagery was a concern. This is a state to state and web camera host to operating party issue, as each states law is different. It is generally appropriate to capture and share web camera imagery. It is generally illegal to capture voice. One researcher mentioned they have a public use properties memorandum for operating unmanned aerial vehicle drones. It states they can only use the drone imagery for research and nothing else.

Web camera data management is important. Considerations for data management should include:

- Access protocols and data usage limitations
- Storage costs
- Format

It would be used to develop a data catalog that incorporates search keywords or attributes that might be common across cameras and the access to their collected video/data. That would be helpful if a developer or programmer wanted to search across a network of cameras for camera(s) with a specific or similar setup, utility, access, etc. to a possible application profile.

There were a few examples provided for image analyses techniques and tools. Amazon Rekognition allows you to automatically identify objects, people, text, scenes, and activities, as well as detect any inappropriate content. TensorFlow™ is an open source software library for high performance numerical computation. Its flexible architecture allows easy deployment of computation across a variety of platforms (CPUs, GPUs, TPUs), and from desktops to clusters of servers to mobile and edge devices.

Challenges were reviewed. When using AI techniques, such as TensorFlow™, the hardware needed to train and run the processing can be expensive. In addition, high performance is gained from using high end graphics cards and the prices of these can be cost prohibitive. Depending on the camera focus and resolution, the applications that could be developed are in the domain of automating a manual/visual object identification/tracking task which might be tedious or unfeasible by a person, but possible and cost-effective using machine learning/visual pattern matching.

Challenges of Maintaining 500+ Cams at Surfline, Inc.

Mark Willis, Surfline | PDF of Presentation

Surfline was founded in 1985. They started mainly for Southern California surfers and are now global. They serve over 4 million users a month and have an estimated 100 employees. The business model relies on subscriptions, advertising and consulting for revenue. There is a wide range of relationships with academia and government agencies. WebCAT was the fist federal grant for Surfline.

Surfline streams over 500+ cameras. They are primarily for recreational purposes on and off platform. They also syndicate to hundreds of news outlets. This is important during an extreme event.

Within Surfline and WebCAT, the biggest challenge is finding a suitable host. Sometimes it can take months of calls and visits. Setting up a web camera is often seen as a distraction; potential hosts are busy.

One major challenge of WebCAT was the Miami camera. Surfline installed three cameras and used Surfline's funds to keep it operational. There was a mix of lightning strikes and faulty cables that damaged the camera. In addition, there were internet service provider issues here due to the hotel switching providers. The other implication is that when we switched out the cameras, USGS had to travel back to Miami to survey the location to solve for lens distortion, position and orientation.

Overall, the WebCAT project was successful for Surfline. It was challenging to manage a small project, they would prefer a large contract. There were some data management issues leading to gaps in data (for example switching from HTTP to HTTPS caused a data gap).

Appendix 2: Workshop Participants

Lisa Adams
Kennesaw State University
ladams@kennesaw.edu

Melinda Bailey
National Weather Service
melinda.bailey@noaa.gov

Fatu Blama
North Carolina State University
fatublama@yahoo.com

Katherine Brodie
U.S. Army Engineer Research & Development Center
Katherine.L.Brodie@usace.army.mil

Lauren Brisley
University of Florida
lbrisley@ufl.edu

Jenna Brown
USGS
jennabrown@usgs.gov

Brittany Bruder
USACE-CHL-FRF
brittany.l.bruder@usace.army.mil

Marie Bundy
NOAA Office for Coastal Management
marie.bundy@noaa.gov

Michael Churma
NOAA NWS MDL
michael.churma@noaa.gov

Greg Dusek
NOAA NOS
gregory.dusek@noaa.gov

Dave Eslinger
NOAA OCM
Dave.Eslinger@noaa.gov

Dave Foster
Axiom Data Science
dave@axiomdatascience.com

Ben Freeston
Surfline
bfreeston@surfline.com

Joe Gilmore
PacIOOS/University of Hawaii
the-cne@hotmail.com

Debra Hernandez
SECOORA
debra@secoora.org

Sharleen Johnson
SCDNR
JohnsonSh@dnr.sc.gov

Joseph Long
University of North Carolina Wilmington
longjw@uncw.edu

Luke McEachron
Florida Fish and Wildlife Conservation Commission
Luke.McEachron@myfwc.com

Hope Mizzell
SC State Climatology Office
mizzellh@dnr.sc.gov

Dennis Murphy
Surfline
dennis@surfline.com

Geno Olmi
NOAA
geno.olmi@noaa.gov

Meg Palmsten
U.S. Naval Research Laboratory
meg.palmsten@nrlssc.navy.mil

Jennifer Plunket
North Inlet-Winyah Bay NERR
jen@belle.baruch.sc.edu

Dwayne Porter
University of South Carolina
porter@sc.edu

Dan Ramage
USC
dan@inlet.geol.sc.edu

Hugh Roarty
Rutgers University
hroarty@marine.rutgers.edu

Scott Stripling
NWS
scott.stripling@noaa.gov

Steven Taylor
NOAA/National Weather Service
Charleston, SC
steven.taylor@noaa.gov

Chrissa Waite
The Baldwin Group @NOAA OCM
chrissa.waite@noaa.gov

Abbey Wakely
SECOORA
abbey@secoora.org

Bethney Ward
USACE
Bethney.P.Ward@usace.army.mil

Mark Willis
Surfline
mwillis@surfline.com