SURF AND NEARSHORE DYNAMICS CAMERA (SANDCAM)

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RESEARCH REPORT NO. CACR-06-06
DECEMBER 2006

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Executive Summary

The Surf and Nearshore Dynamics Camera (SANDCam) project was initialized at Rehoboth Beach in April, 2006. The project serves as an inexpensive, real-time monitoring tool for beach evolution allowing for the generation of time series of shoreline and planform morphologic variability. The project was supported by the Shoreline and Waterway Management Section in the Division of Soil and Water at the Delaware Department of Natural Resources and Environmental Control (DNREC). In all, seven cameras were located atop the Henlopen Hotel along the boardwalk at Rehoboth Beach. The field of view of the seven cameras spans from roughly Herring Point in the north to about 2.5 km south of Rehoboth Avenue. Hourly daylight imagery is collected from each camera by a local computer and then automatically sent via the internet to University computers. Once at the University, automated algorithms transfer the images to a hierarchical directory tree. Images for each hour are then automatically geo-referenced to a local coordinate system and merged together to form a single composite image providing an overhead bird's eye view of the beach. Automated algorithms locate the shoreline for each hourly image with the positioning being archived for statistical analysis. Raw and geo-referenced imagery as well as shoreline products are displayed hourly on http://sandcam.coastal.udel.edu.

The project has served as the basis for a Master's Thesis for Nathaniel Pearre. Imagery and methodology has been presented at the 2 most recent Coast Days. A kiosk with a PowerPoint presentation describing the imaging methodology and reasons for installing the SANDCam site will be set up in early 2007.

Introduction

1.1. Location, Census and Economy

Rehoboth Beach is located on the exposed Atlantic coastline in Sussex County, Delaware. According to Census data, as of 2005 Rehoboth beach had a population of only 1,544 persons. The average home price was around $511,000 and nearly 75% of the homes and apartments are routinely unoccupied. However, during the summer tourist season, tens of thousands of people flood the city to shop at local outlet malls, cruise the boardwalk, swim in the ocean and sun bathe on the beach. It is therefore necessary to understand and monitor the physical processes occurring along the coast to protect this valuable real estate.

1.2 Oceanographic Setting

The Atlantic Delaware Coastline absorbs wave energy from both the north and south. In the late fall and winter, nor'easters and large winter storms tend to bring wave energy from the north. However, due to the proximity and location of New Jersey, the shoreline is largely sheltered from swell originating far offshore. The coast is not "protected" from local storms due to this effect. In the summer and early fall southerly storm activity can reach the coastline unencumbered with essentially an infinite fetch. Due to the effect of these end member processes, the net transport of sediment along Rehoboth Beach tends to be northerly. The ultimate fate of sand moving in this direction is residence on Hen and Chicken Shoals or more likely on Cape Henlopen as evidenced by the drastic volumetric increase in material over the last 100 years. Further south, near Fenwick Island, there is a nodal point [*Mann and Dalrymple*, 1986] where the sheltering effect of New Jersey is negated and the net transport of sediment is to the south driven by, in a net sense, the larger forcing conditions from the north.

Due to the net conditions occurring at Rehoboth Beach and indeed much of the Atlantic Delaware coastline, the whole shoreline is in a regressive state. Sea level rise (and sinking of the Delaware Atlantic Coast [*Kraft and John*, 1976]) and the lack of sediment supply imply continuous shoreline recession. While the groins to the north of Rehoboth Beach alter the shoreline, they are not solely responsible for the shoreline erosion along the coast as can be seen in Figure 1 where the shoreline was eroding long before the groins were installed. This effect is also evidenced by the fact that the World War II towers south of Herring Point are now often in the swash zone whereas they were originally built behind the dunes.

Due to the fact that numerous businesses and homes line the Delaware coastline and that activities related to the beach itself bring in large sums of tourism dollars to the region, the coast has undergone man-made modifications in an attempt to lessen its erosive tendency. DNREC has undertaken numerous beach nourishment projects with the most recent occurring at Rehoboth Beach in the summer of 2005. It is this and future nourishment efforts that SANDCam was installed to monitor and investigate.

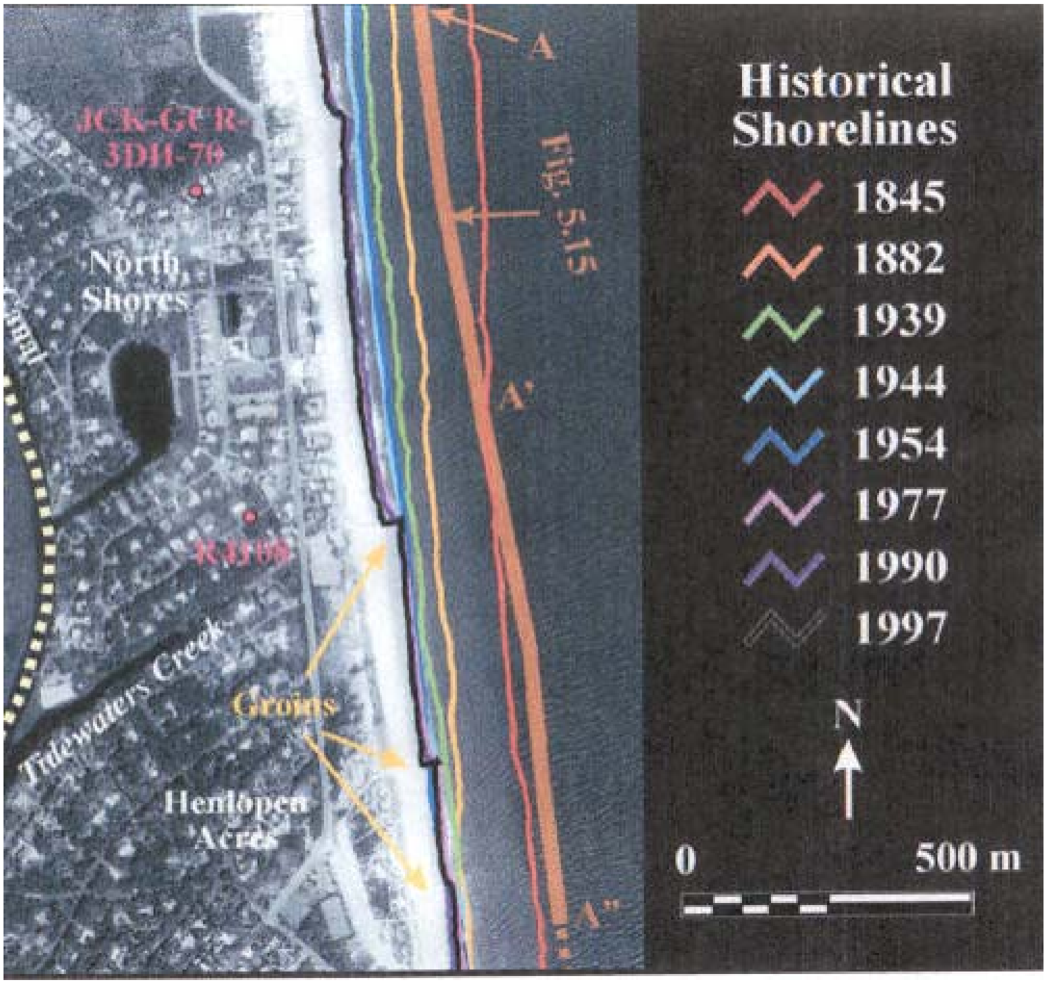

Figure 1. Historical shoreline change along the coast north or Rehoboth Beach Delaware. Image Credit: Maria Honeycutt

In April of 2006, the project required the installation of seven video cameras atop the Henlopen Hotel to monitor changes in the beach (Figure 2). Our goals were to utilize a commercial control computer to collect beach imagery, upload to local computers at the University of Delaware, develop automated image processing algorithms to create merged, geo-referenced imagery and develop automated algorithms to identify the shoreline location within the imagery. Further, the project required the dissemination of imagery to a web-based display in near real time. These goals have been met and are described herein.

Figure 2. Images taken from Rehoboth Beach showing the Henlopen Hotel and camera positions.

2. Hardware and Image Transfer

2.1 Computers

The computers (2) used in this project were purchased from Erdman Video Systems (http://www.video-monitoring.com). They are essentially stripped down Pentium computers in an environmental housing (Figure 3). The computers contain Erdman software that allows for the capture of imagery from up to 4 cameras per computer. The software enables the collection of snapshot, time exposure, variance and pixel time series that cannot be routinely captured with other commercial software. Furthermore, the relatively inexpensive cost of an out-of-box-solution versus the procurement of new computers without software made the Erdman system the logical choice. Each computer is connected to an APC Uninterrupted Power Supply (UPS) to reduce the chance of voltage spikes damaging the system.

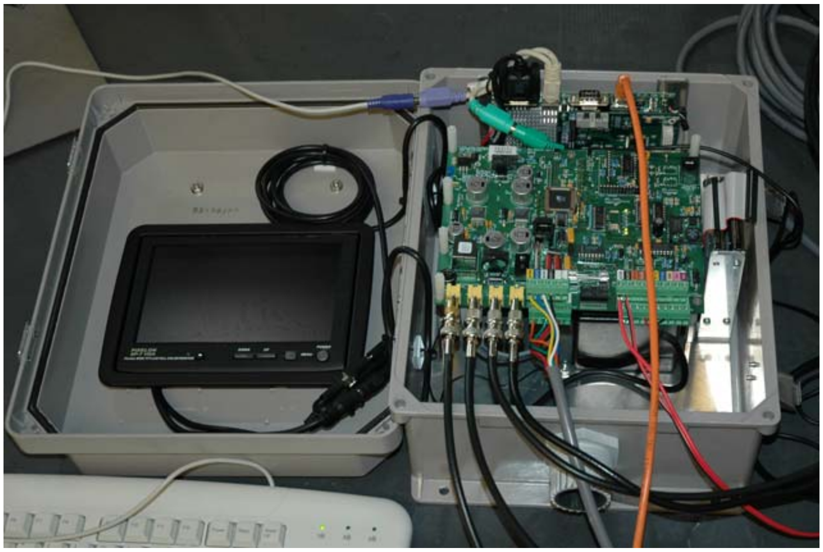

Figure 3. An image showing the collection computer contained in the environmental housing. The 4 black cables are the video inputs and a small monitor is included in case on site trouble shooting is required.

2.2 Cameras and Lenses

All cameras used in this project were Panasonic high-resolution color surveillance video cameras (WV-CL920A; Figure 4) with 640 x 480 pixel resolution and a 1/2" interline transfer CCD. Each camera was fitted with a Pentax or Rainbow lens of varying focal length depending on look direction (Table 1). In addition, each lens was fitted with a Hoya linear polarizing filter to reduce glare.

Figure 4. The Panasonic camera used in this study.

Table 1. Camera direction, lens type and focal length

Camera	Direction	Lens type	Focal Length (mm)
1	South	Pentax	12
2	Southeast	Pentax	9
3	East	Rainbow	3.5
4	Northeast	Pentax	9
5	Northeast	Pentax	12
6	North	Pentax	25
7	North	Pentax	50

2.3. Housings, Mounts and Connections

Each camera was placed into an environmental housing (Pelco). Housings were attached to Pelco pedestal mounts that were affixed to an in-house-engineered platform (Figure 5). Platforms were located in the northeast and southeast corners of the Henlopen rooftop. Several lead bricks were placed inside each platform and 5 sandbags were placed on top of each platform to increase weight and reduce the chance of movement during high winds. As a safety precaution, a ¼" steel cable was threaded through each platform and secured to robust steel I-beams roughly 100 feet away (Figure 6).

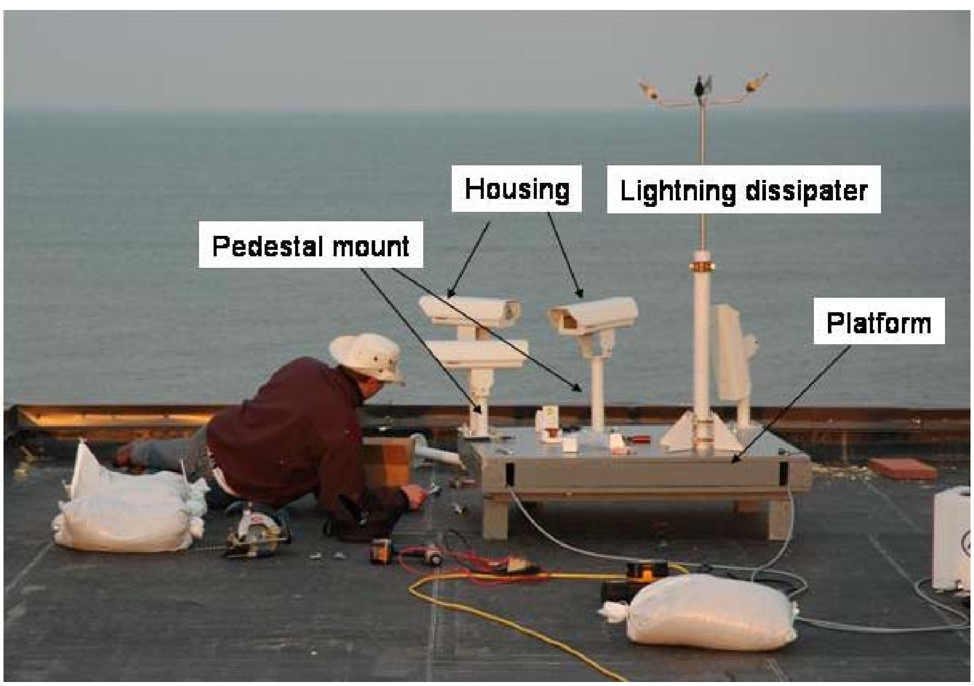

Figure 5. Picture showing the camera installation on the Henlopen Hotel rooftop. The gray platform can be seen, here elevated on blocks, during the construction process.

Each camera was attached to a video line arrestor to reduce the likelihood of inductive lightning surge damaging the unit. In addition, a lightning dissipater array (Figure 5) was affixed to each platform in an attempt to reduce electricity in the air in the immediate vicinity of the platform. All power and video cables (exterior grade RG59/U coaxial) were run roughly 200 ft along the side of the Henlopen rooftop and into the elevator control room. Here, the video cables were again passed through a video line arrestor to reduce the chance of inductive charge damaging the computer systems (Figure 7). The line arrestor grounds were all connected to a grounding plate that was tied into the downward going ground of the building. The video cable from each line arrestor is connected to one of the BNC inputs on the computers. Two ethernet cables connect the computer to a cable modem that allows for data transfer to University of Delaware computers.

Figure 6. Image showing the grounding cable and safety cable being anchored back to I-beams located roughly halfway across the roof top.

2.4 Site Maintenance

Site maintenance is small. Occasionally someone needs to go to the Henlopen Hotel to wash dirt off the housing glass plate. We have not had any computer difficulties at this stage. If the cameras are moved, which has happened due to painters and roof damage from a storm, they need to be re-positioned and re-surveyed.

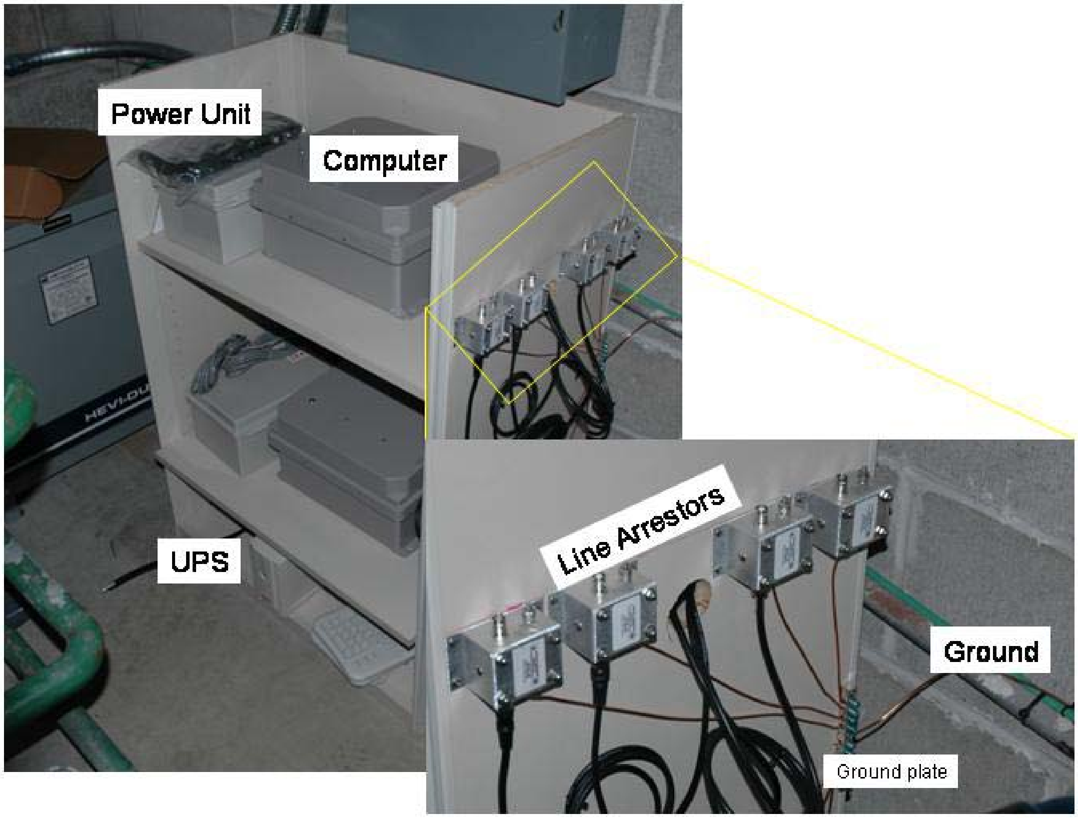

Figure 7. Image showing computer setup in the elevator control room. Inset shows the line arrestors used to mitigate inductive surges.

2.5 Data Archiving.

Data that is received at the University of Delaware is immediately moved to a hierarchical directory tree based on time. The machine that houses the data is a 6 disk redundant RAID array that essentially maintains a means to recover files if a disk crashes. In addition, we periodically make 2 copies onto DVD.

3. Lens Distortion

All lenses have inherent distortion due to glass curvature and imperfections in the manufacturing process. Most lens distortion occurs at the image edges where barrel distortion plays a key role. The most obvious distortions are seen with fish eye lenses that have extremely wide fields of view (for SANDCam the offshore looking camera). Narrow angle field of view lenses have much less distortion. If we seek to extract quantitative information from the acquired imagery then any lens distortion must be accounted for. We apply the procedure defined in *Holland, et al.* [1997] assuming the lens distortion is radially symmetric and modeled with an equation of the form

$$k = D_1 r + D_2 r^3 \qquad (1)$$

where k is the amount of distortion and D_1 and D_2 are distortion coefficients that are solved for, and depend on, the radial distance from the center of the lens and that distance cubed.

To determine lens distortion, a pattern of white dots on a black background is set up parallel to the camera's focal plane (perpendicular to the camera, Figure 8). A series of images is captured with a single lens/camera pair. We maintain lens/camera pairs to decrease any chance of additional errors associated with possible tangential shifts between the lens center and that of the CCD array within a camera. Once the dot pattern is captured, algorithms are used to define the center of mass of each dot (Figure 8). Since the lens has distortion, the dots' centers of mass are not located in the expected position if no distortion occurs. This allows us to determine the amount of distortion based on the difference of where the dots are found and where they should be (Figure 9). The errors (differences) are then fit to a function of the form given by equation (1) (Figure 9). Once the distortion is known, the image distortion can be corrected and much of the pixel difference can be accounted for (Figure 10). Not all errors can be accounted for in this manner because some of the error is not perfectly radially symmetric and some error can result from tangential distortion. Nevertheless, corrected distortion that leaves us with around 1 pixel error in this extreme case is expected. Note that the pixel error in the zoom lens cases is on the order of 0.07 pixels.

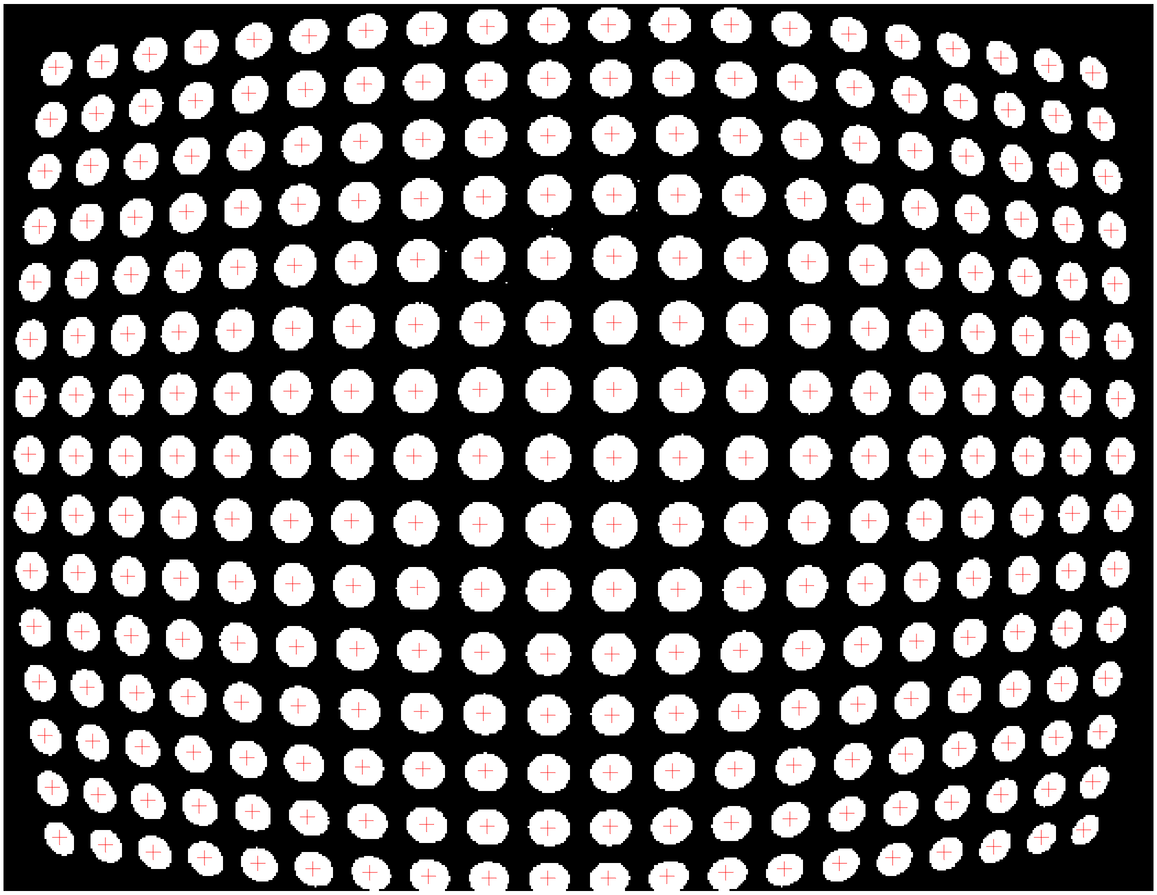

Figure 8. Dot pattern used to calculate distortion of each lens. The red crosses are the automatically detected dot centers that are used to determine distortion based on their shift from the expected position if no distortion occurred.

4. Image Analysis

The SANDCam deployment consists of seven cameras that collect four different image types per hour during daylight conditions. With this large stream of data it becomes necessary to develop automated algorithms to perform quantitative analysis because even the most diligent graduate student or researcher will rapidly become overwhelmed at the task of manual interpretation. Automated algorithms include applying distortion (Section 3), rectification (Section 4.2) and shoreline identification (Section 4.4).

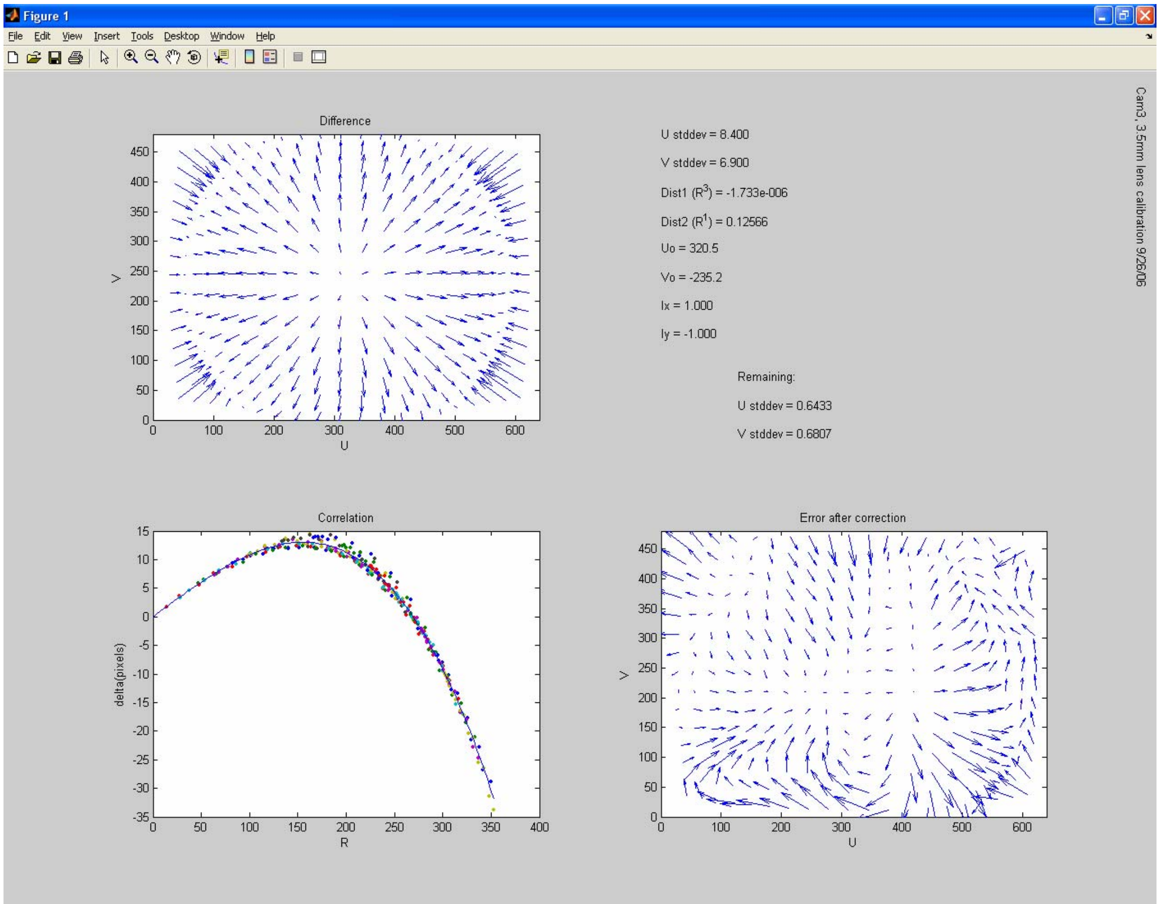

Figure 9. Screen capture of the analysis of a 3.5 mm lens. The upper panel shows the barrel distortion effect and the offset of the found and expected position of the white dots. The lower left panel shows the pixel error as a function of the distance from the center (radially) and the fit line (blue) based on equation (1). The lower right panel shows the remaining pixel error after accounting for distortion. It is important to note that the vector scales between the upper panel and that in the lower left are NOT the same.

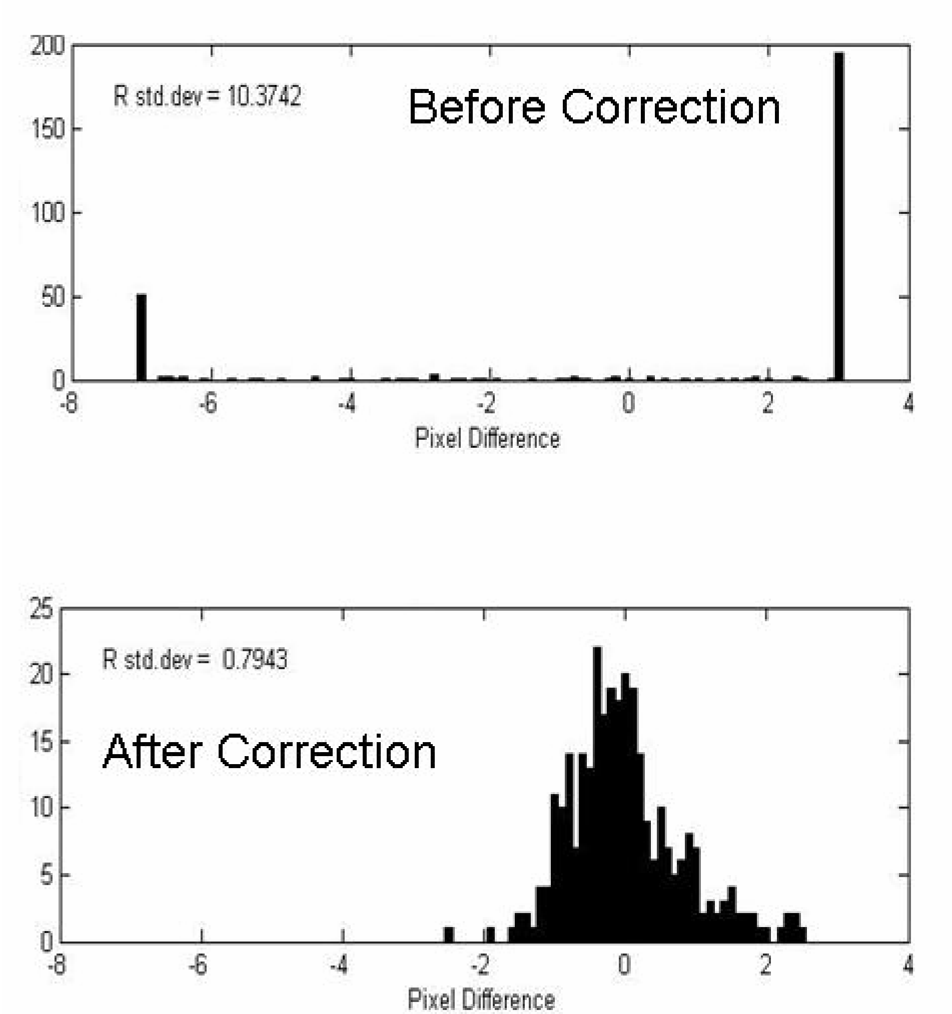

Figure 10. Histograms of the pixel differences before and after distortion correction for the 3.5 mm lens.

4.1 SANDCam Image Types

SANDCam collects four types of imagery consisting of a snapshot, a time exposure image, a variance image, and a time stack.

<u>Snapshot</u>

A snapshot image (Figure 11) is directly analogous to the type of image one would collect with a standard hand held digital camera. Snapshots give us a general feel for surf zone conditions but make it difficult to extract quantitative information because the image only captures a single instance in time.

Figure 11. Snapshot taken from SANDCam camera 7 looking north towards Herring Point and the World War II towers using a zoom lens.

<u>Time Exposure</u>

A second type of image that is collected is known as a time exposure, or "timex" for short (Figure 12). A time exposure image is analogous to using a very slow shutter speed on a standard hand held digital camera. In the SANDCam application, rather than altering shutter speeds, we collect 10 minutes of imagery at roughly 5 Hz and save to the image buffer. The images are then averaged over time to yield the timex. Compare Figure 11 to Figure 12. The two images were created within 10 minutes of each other. Notice how in the snapshot image individual waves are clearly visible and the shoreline is seen to meander along the coast resulting from individual runup events and intersecting wave trains. In the timex, though, the wave breaking and runup are smoothed out over the 10-minute time span leaving a broader area of high image intensity. This region of image intensity denotes the location where waves first break, on average, and where the time-averaged shoreline is located. Later sections describe how these are chosen in an automated sense.

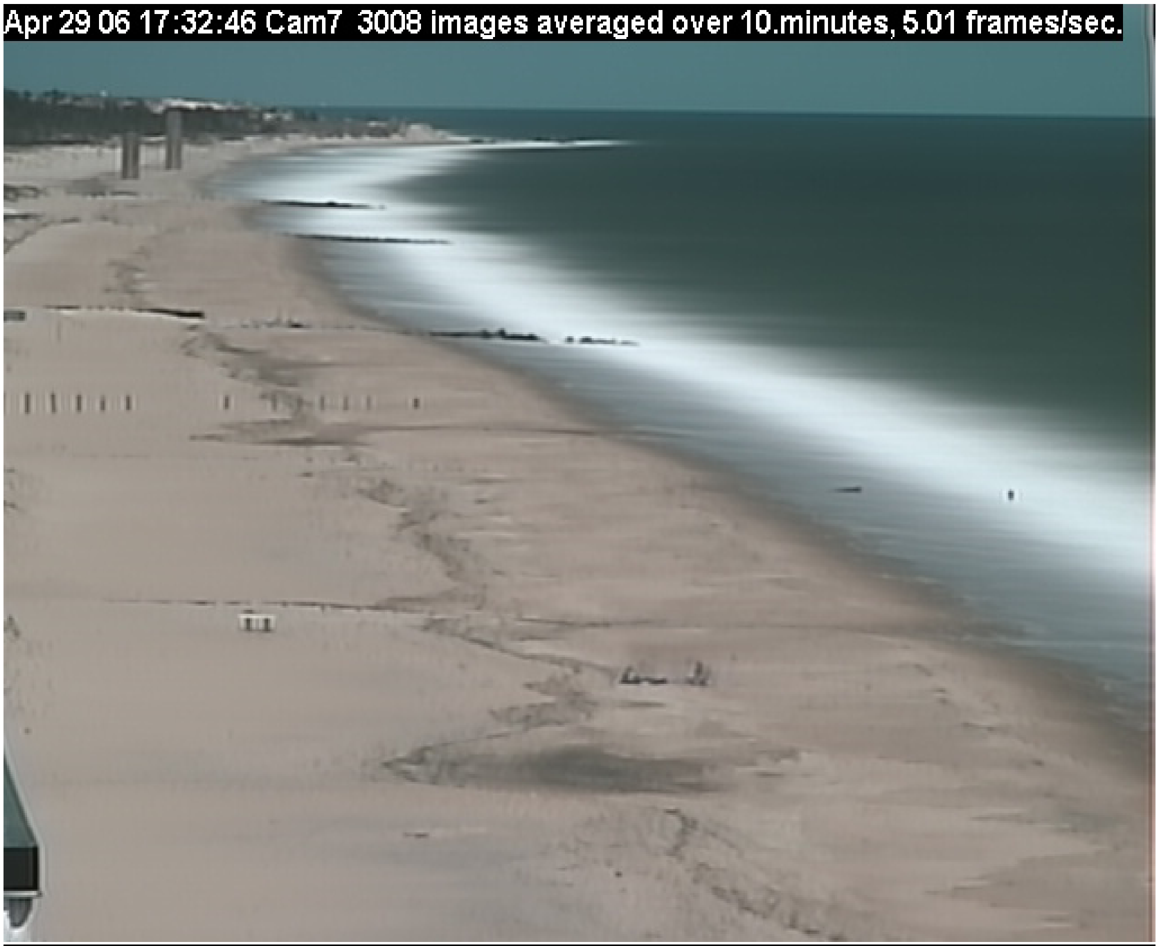

Figure 12. Time exposure, "timex" image taken from SANDCam camera 7 looking north towards Herring Point and the World War II towers using a zoom lens. Image time is roughly the same as for Figure 11.

<u>Variance</u>

The third type of imagery that is collected via SANDCam is known as a variance image (Figure 13). Whereas the timex was the average in image intensity over 10 minutes, the variance yields the variability in image intensity over the same 10 minutes. Regions of low variability are mapped to black and regions of high variability are mapped to white. The variance image is important because it also helps us identify the shoreline and breakpoint regions. Comparing the timex and variance we see that in the timex case the water is bluish offshore. However, the variance shows black offshore because over the 10 minutes, the color of the water is roughly constant (hence low variability). Near the shoreline, a white band is observed. Here, the water color changes from bluish to white and back again as breaking waves pass. This implies a large amount of variability in pixel intensity which leads to "bright" regions in the variance image.

Figure 13. Variance *image taken from SANDCam camera 7 looking north towards Herring Point and the World War II towers using a zoom lens. Image time is roughly the same as for Figures 11 and 12.*

<u>Time Stack</u>

The final type of image that can be collected from SANDCam is known as a time stack. Here, rather than sampling the entire image for a given period of time, only a select number of pixels are collected. An example of some pixels of interest are shown in Figure 14. These lines of pixels are sampled over roughly 17 minutes at 2 Hz to yield a runup time series (Figure 15), that can be used to map swash zone process. Other time stacks can be used to estimate wave period, direction and bathymetry. At this stage, we have not incorporated time stacks into SANDCam analysis as the focus for this project was shoreline identification and planform area analysis. Future proposals will seek funding to continue working on automated algorithms to bring SANDCam's full potential to fruition.

Figure 14. Image from the offshore looking camera (camera 3) showing the location of 6 lines of interest over which time stacks were collected.

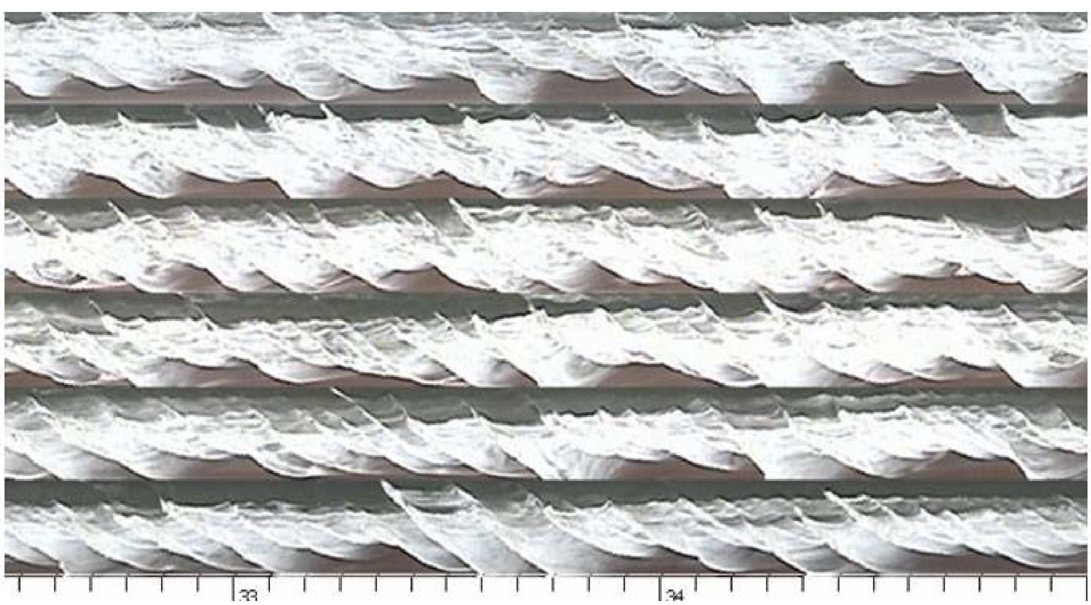

Figure 15. Wave runup as seen from the time stack image. Offshore is to the top of each image strip. The scale on the bottom is in minutes.

4.2 Geo-Rectification

Until now, images have been discussed solely in a qualitative sense. In order to investigate shoreline variability, quantitative analyses must be performed. To do this requires that each image be geo-referenced into some local coordinate system. We have developed a local coordinate system that has the y-axis running along the boardwalk and the x-axis normal to it with our (0,0) located just in front of southern wall of the Henlopen Hotel on the boardwalk. We also have simple transformation routines that allow us to convert any local coordinate into Delaware State Plane and back as necessary.

To perform a geo-rectification for each camera, we follow the method of *Holland, et al.* [1997]. The procedure requires that we determine some extrinsic parameters related to the camera such as its (x,y,z) position and its tilt, azimuth, roll and field of view. Through surveying, we know the cameras position. The other parameters must be determined by solving a set of collinearity equations using the known three-dimensional coordinates and pixel coordinates of fixed objects and ground control points (GCPs) contained in the imagery (Figure 16). Fixed objects might include street lights, fence posts, groin ends, signs or World War II towers. We also constructed numerous GCPs out of peg boards in sizes ranging from 2 to 8 feet in diameter. GCPs are painted black to enable them to be easily seen in the imagery.

Figure 16. Snapshot image showing fixed and emplaced ground control points (GCPs) denoted by white arrows.

After camera deployment, objects and GCPs were surveyed by the DNREC survey crew and coordinates were subsequently transferred to our local system. The set of collinearity equations is then solved in a least squares sense yielding the unknown parameters allowing for any pixel to be converted from its (u,v) image coordinates to (x,y,z) real-world coordinates (Figure 17).

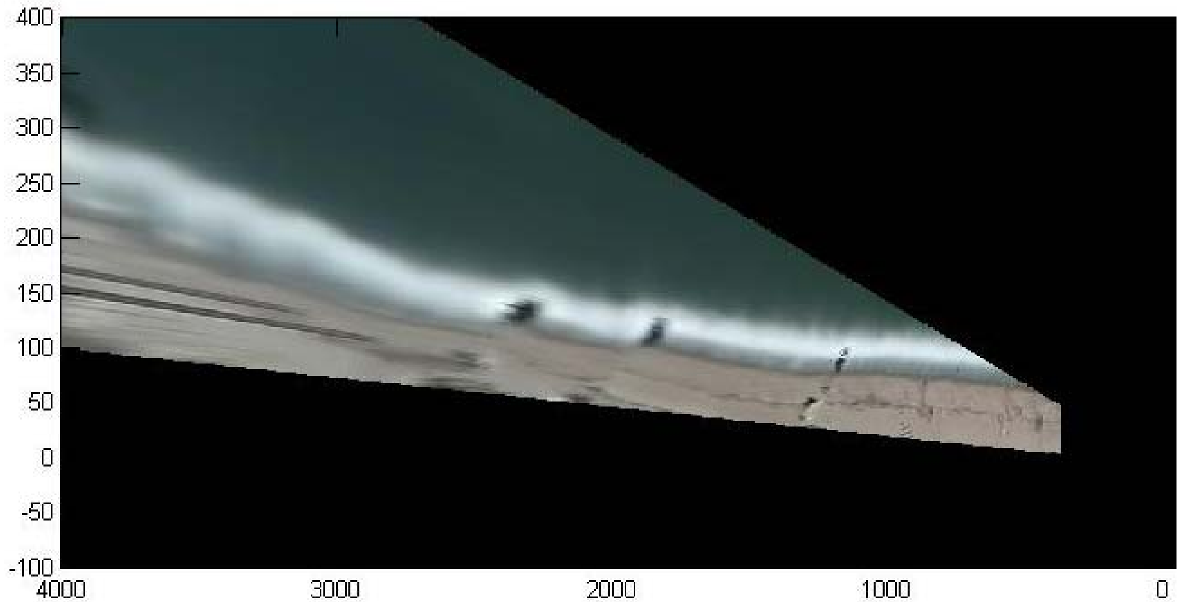

Figure 17. The geo-rectified image (local coordinates) corresponding to Figure 16. Areas outside the cameras field of view are mapped to black. Numbers on the axes are the coordinate scales in meters.

Since the conversion occurs from a 2D image world to a 3D real world, the system is underdetermined requiring us to specify one of the unknown coordinates. In our case, we always specify the vertical coordinate as tidal level. We use the tide for the time of interest based on harmonic analysis data using the freely downloadable xtide software package (www.eos.ubc.ca/~rich/). Since no tidal data based on this procedure is available for Rehoboth beach, we take the average of the two nearest stations at Lewes and Ocean City Maryland. For objects that have little vertical relief this poses little problem. However, for objects with much vertical relief, they get essentially laid over onto the beach. An extreme example of this can be seen in Figure 17 where the World War II towers near Herring Point appear to be laying on their sides. Now that the images can be cast into a local coordinate system, any identified object can be given a real-world coordinate location and allows for the direct scaling and measuring of features such as shoreline locations, breakpoint locations, and surf zone widths.

4.3 Merged Imagery

Once the geometrical information for each camera is obtained through rectification procedures, all camera imagery can be mapped into a single composite image that is analogous to an overhead, bird's eye view (Figures 18 and 19). From the roof of the Henlopen Hotel, we have developed merged imagery that spans nearly 6.5 km of beach from roughly Herring Point in the north to about 2.5 km south of Rehoboth Avenue. We have applied procedures to deal with overlaps between cameras. In addition, we have developed a means to retain the resolution in the far field where zoom cameras overlap less resolved cameras.

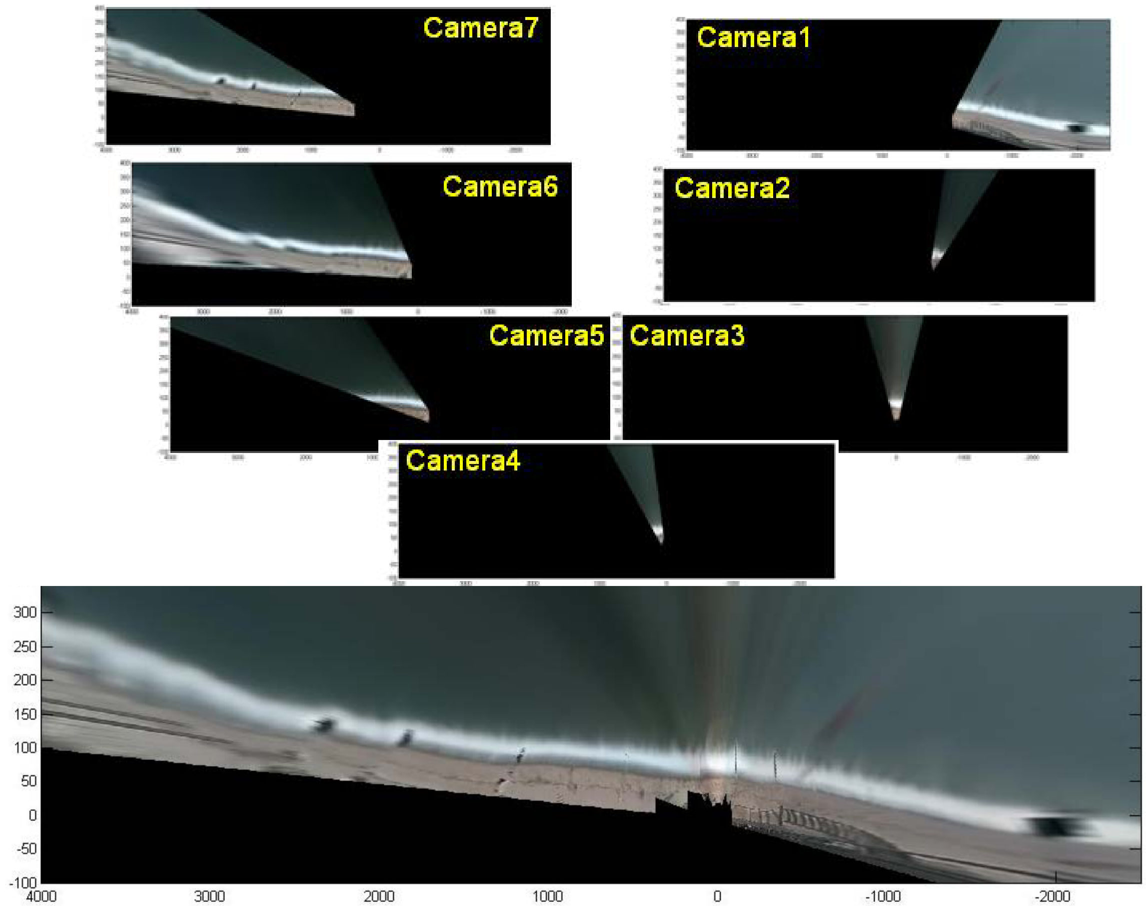

Figure 18. Individual rectified images and the composite timex merged image.

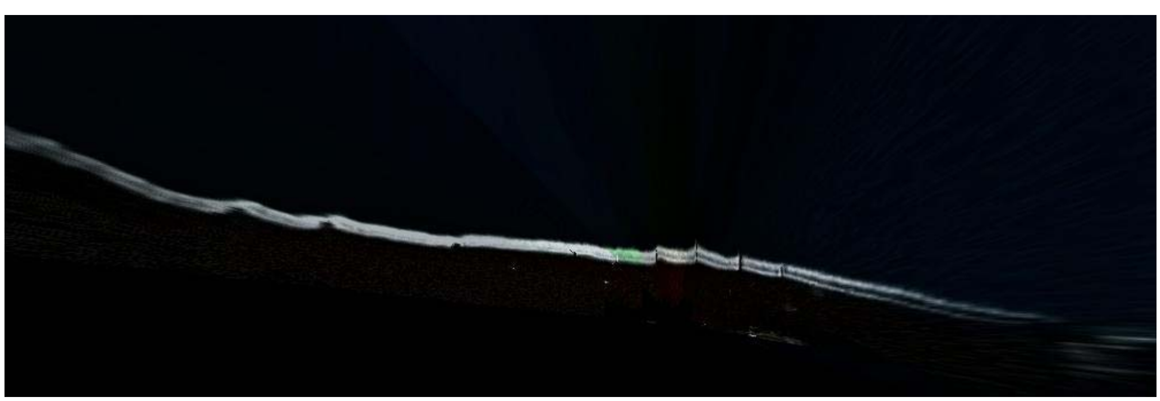

Figure 19. The merged variance image.

4.4 Shoreline Identification

The key to using the image data relies on developing robust automated algorithms that can locate the shoreline for each time of interest. It should be noted that wave breakpoint locations are also found from the methodology described below. The merged or variance image (in most cases) clearly indicates the location of the shoreline where the pixel color changes from brown to white (timex merge) or from black to white (variance merge). In some instances, the shoreline is less discernible in the variance merge than it is in the timex merge or vice versa. Thus, we seek to utilize both images in detecting the shoreline (see figure 20). The first step is to create a single intensity plane from the 3-color timex merge by taking the sum of pixel intensities across the three color planes (red, green, blue). The second step does the same procedure but applies it to the variance merge. Finally, the two modified images are added together to yield an image where the peak in intensity near the shoreline is more identifiable than pixels landward or seaward.

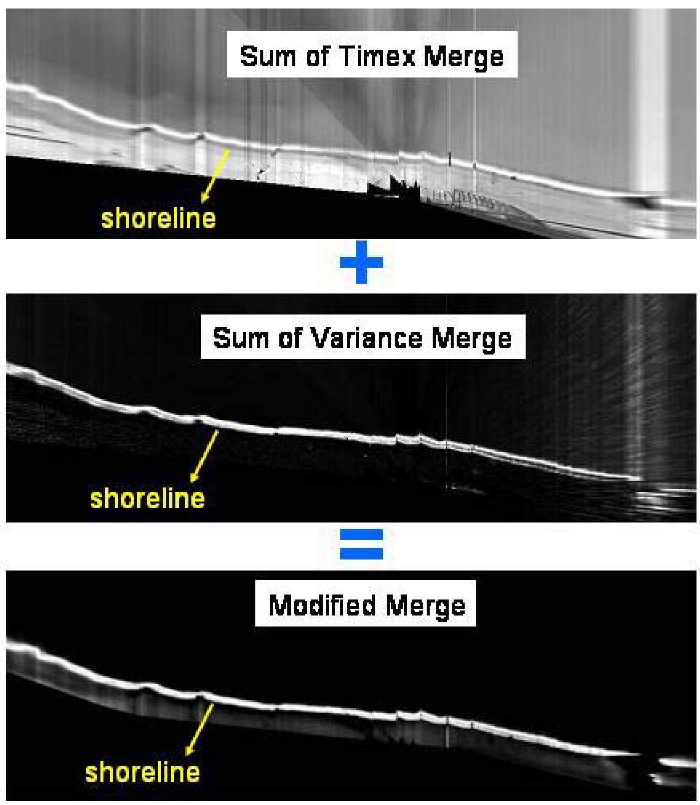

Figure 20. Schematic describing how a modified image is obtained in an attempt to highlight and isolate the region near the shoreline.

The modified image now consists of only a single color intensity plane that we can interrogate to locate the shoreline. Each column of the image is extracted one by one and the peak in intensity is determined. The shoreline does not correspond to the peak.

However, the peak lies landward where the intensity level drops (Figure 21). We have determined that this occurs at roughly the mean intensity obtained from intensities starting at the peak and extending landward half the distance of a maximum expected surf zone width (cyan distance in Figure 21). Where the mean intersects the intensity curve is chosen as the location of the shoreline and is marked by the circles in the upper panels.

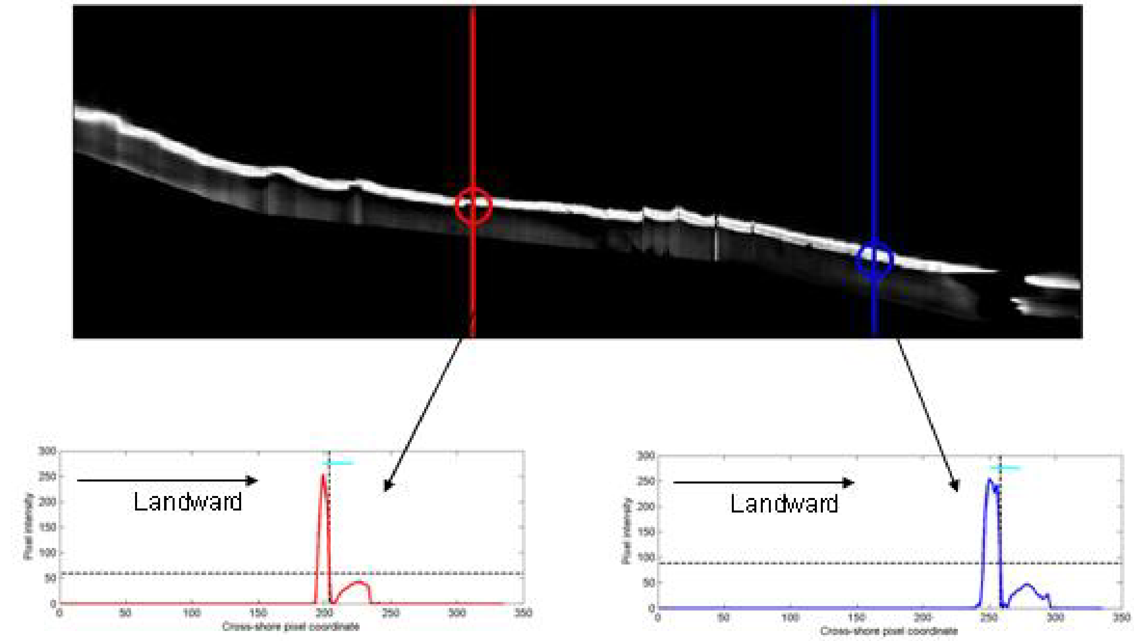

Figure 21. The modified merge image (upper panel) where two columns of the image have been extracted to demonstrate how the shoreline is identified. In both the red and blue curve cases (lower panels) the intensity shows a peak corresponding to the bright region. We take the average of pixel intensities over the distance denoted by the cyan line. Where the intensity curve crosses the average intensity, the shoreline is chosen as indicated by the dashed lines and the circles in the upper panel.

The procedure is repeated for each column until the shoreline is mapped (Figure 22). At this stage we are just beginning to develop quality control procedures to determine if the value chosen for the shoreline is reasonable.

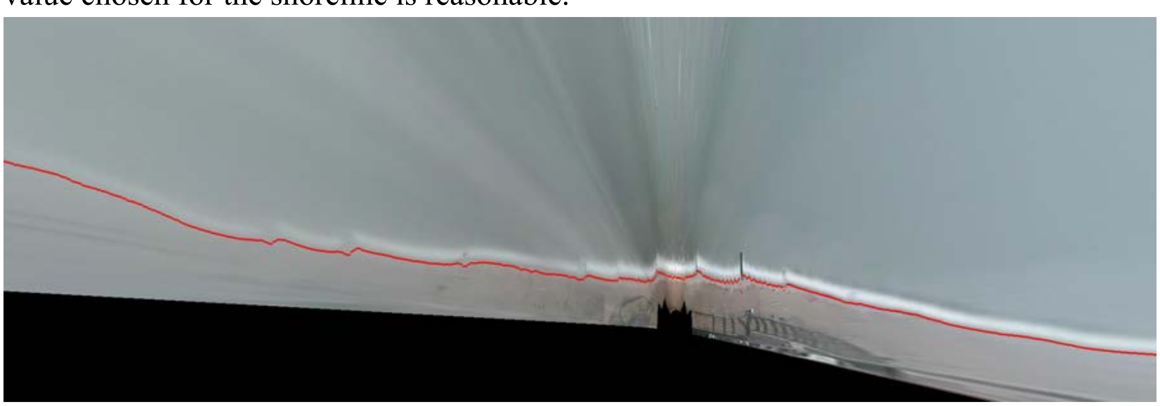

Figure 22. Merged timex image with the automatically chosen shoreline following the above procedure shown in red.

5. Preliminary Results

As mentioned above, we are just starting to perform quality control procedures on the data and thus the analysis is now underway. Below we present some preliminary data from two storms, including Ernesto that passed through the Rehoboth Beach area on August 30th, 2006.

Figure 23 shows the wave height and period surrounding the storms as recorded by NDBC Buoy # 44009 located approximately 20 miles offshore of Bethany Beach. In addition, 2 merged timex images with the corresponding shorelines are shown. The final subplot shows the pre-storm shoreline subtracted from the post-storm shoreline and quantifies the change in planform area observed for this single event. More erosion appears to occur in the southern end of the beach where less shore protection exists and perhaps more sediment initially existed due to the previous nourishment. We will be able to produce more data of this type once all quality control procedures have been implemented.

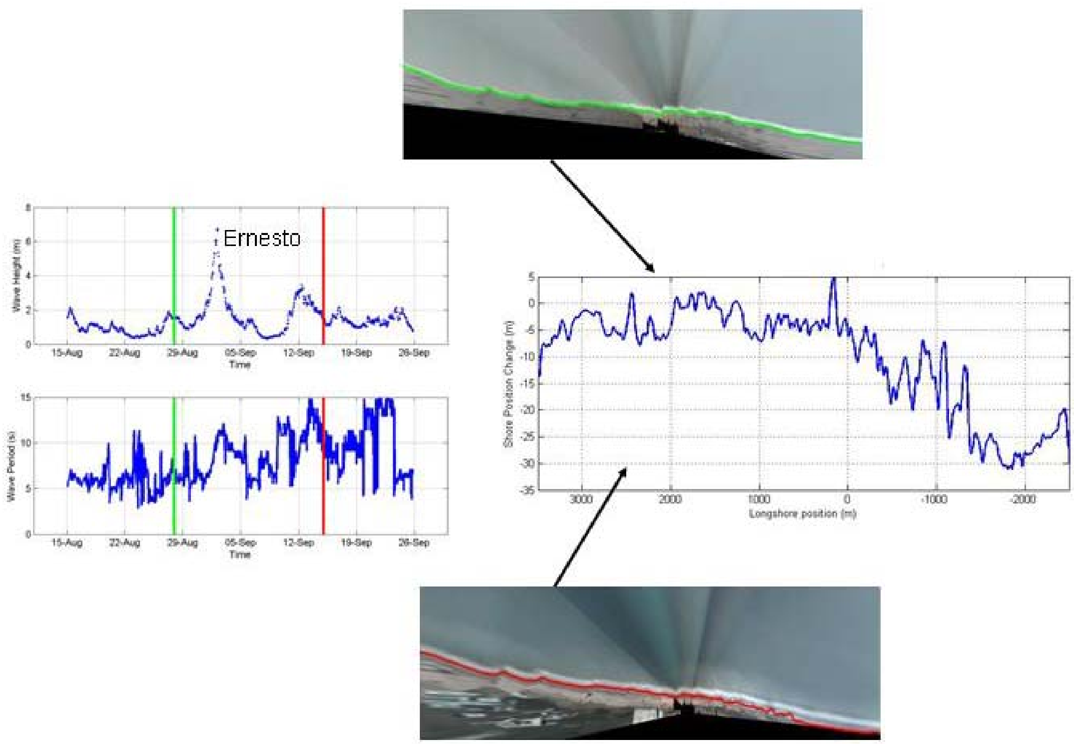

Figure 23. Snapshot of data surrounding Ernesto and subsequent storm. Left panels indicate the wave height and period as collected from Buoy 44009. The red and green lines indicate the date which the shoreline data was collected. The automated shoreline routine returned the shorelines shown in the two merged timex images (green: pre-storm and red: post-storm). The right subplot shows the shoreline change between pre- and post-storm conditions. Negative values indicate shoreline recession.

In addition, we have extracted the shoreline location time series from the three alongshore positions shown in Figure 24 to provide an example. The shoreline time history (Figure 25) shows variability on a tidal period as the sea level transgresses and recedes. There are also longer term changes that can be seen over the course of the run. It is important to note that the shoreline runs at an angle to the local coordinate system and is responsible for the offset seen between the time series. These changes in shoreline location will be cast into a planform area in the next step of analysis to determine how the shape of the beach changes over time.

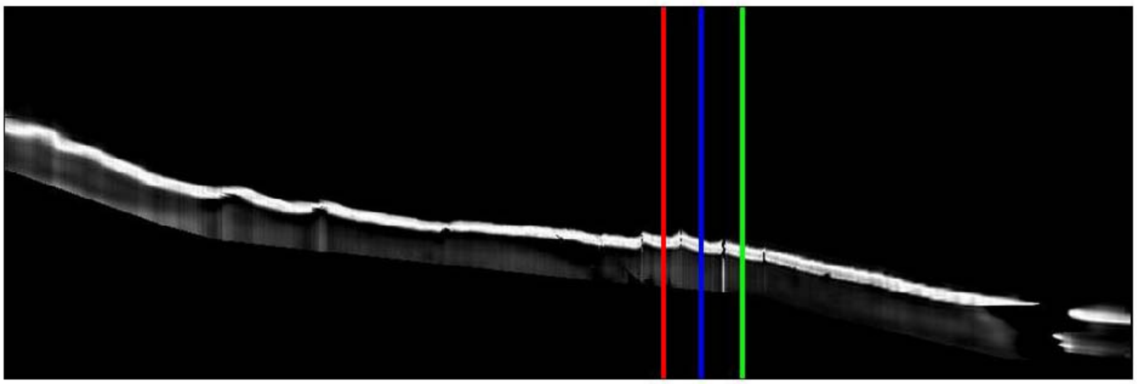

Figure 24. Modified merge image showing the location of shoreline extraction for time series presentation.

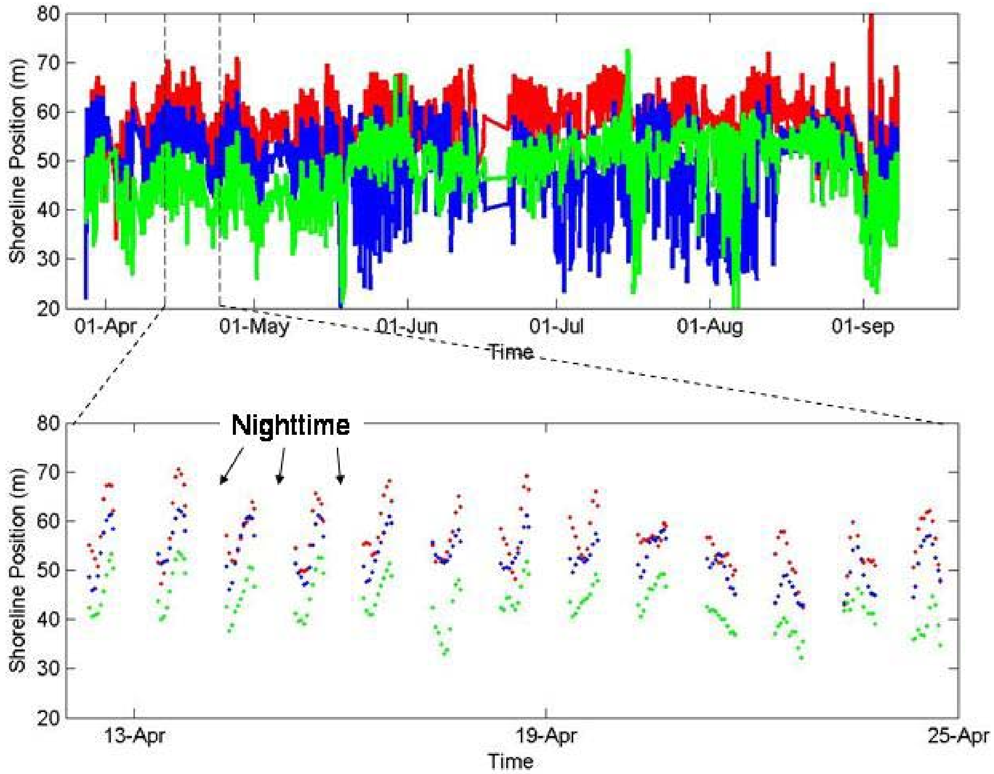

Figure 25. Upper panel shows the shoreline position time series extracted at three alongshore locations near the Henlopen Hotel in 2006 (shown in Figure 24). Lower panel shows a blow up of the small section of time denoted by the vertical dashed lines. Wide time series gaps occur at night when no imagery is collected. Individual bursts of data are collected during daylight hours and show obvious tidal trends in shoreline position. Longer term trends can be seen as well.

6. Web Dissemination

At this stage, all processing that is being completed for the Rehoboth Beach SANDCam site is being performed with no user in the loop. Once the data is auto-processed a new web page is immediately generated and posted to sandcam.coastal.udel.edu (Figure 26).

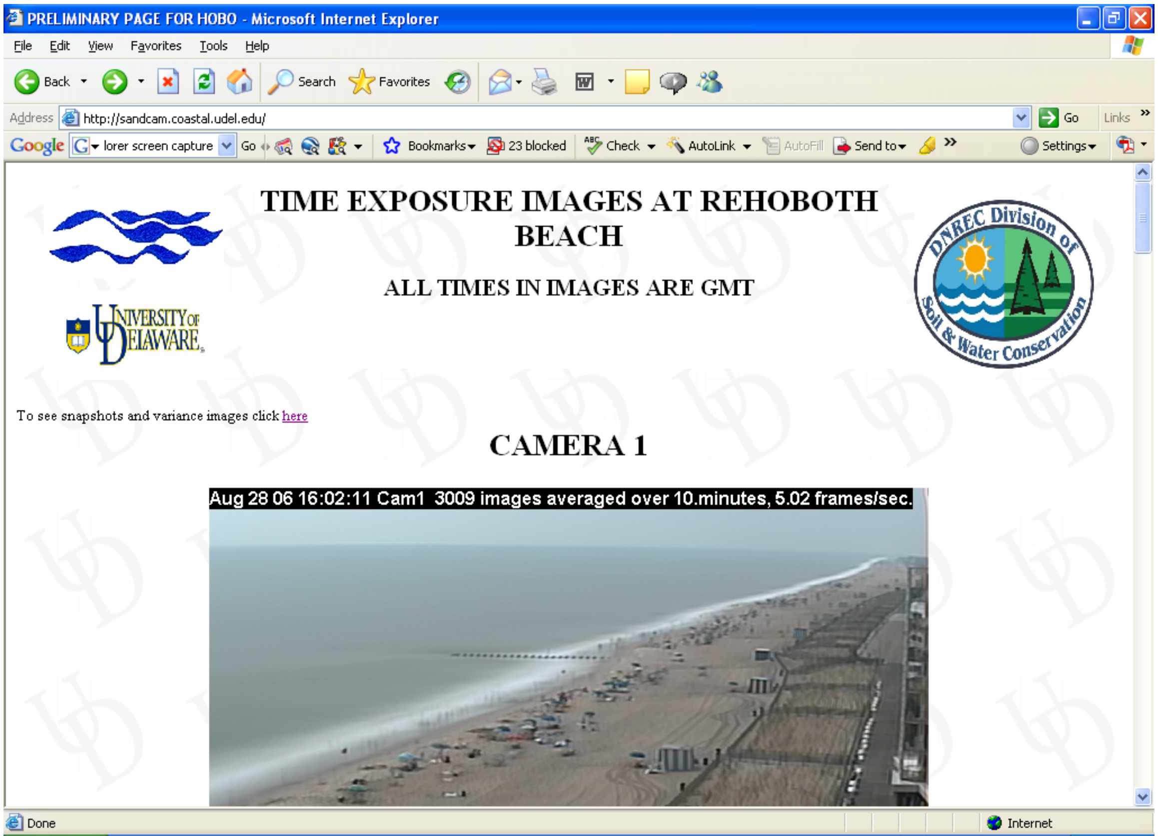

Figure 26. Screen snapshot of the SANDCam web page.

7. Acknowledgements

We would like to thank Anthony P. Pratt, Program Administrator, Shoreline and Waterways Management Section, Division of Soil and Water, Department of Natural Resources and Environmental Control for funding this project. Use of the roof top of the Henlopen Hotel and assistance from Jeff Kiscadden and Stephen Collins is acknowledged. Assistance and collaborative code development with the Naval Research Laboratory and the Coastal Imaging Laboratory at Oregon State University are greatly appreciated.

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9. Appendix

9.1 Appendix A. Outreach

As part of the project, we feel it is necessary to help educate residents and visitors to Rehoboth Beach on the processes that are occurring along the coastline as well as to the purpose of the SANDCam set up. With assistance from Dr. Wendy Carey, we have developed a PowerPoint presentation that instructs the public on SANDCam usage. The presentation will exist on a computer either in the new life guard building or in the City Hall Municipal Building. The site will be determined before Summer, 2007. The PowerPoint slides contained in the presentation are included in this appendix.

Surf And Nearshore Dynamics Camera:

SANDCam at Rehoboth Beach

A short slide show describing the research being performed using the cameras on the Henlopen Hotel

Funded By DNREC

WHY REHOBOTH BEACH?

CHANGING SANDS AT REHOBOTH

Note historical regression of shoreline **before** groin construction

Arrows show corresponding groins between figures

Figure credit: Maria G. Honeycutt

CHANGING SANDS AT REHOBOTH

- Delaware coast is experiencing erosion.
- Sand-starved system
- Major sinks: Cape Henlopen and Hen and Chicken Shoals

RECENT AND ONGOING NOURISHMENTS

Photos courtesy of Delaware DNREC

SANDCam NEED

- DNREC requires a means to routinely and affordably quantify physical processes occurring on Rehoboth Beach

- SANDCam provides a means to determine shoreline and beach evolution in an automated fashion

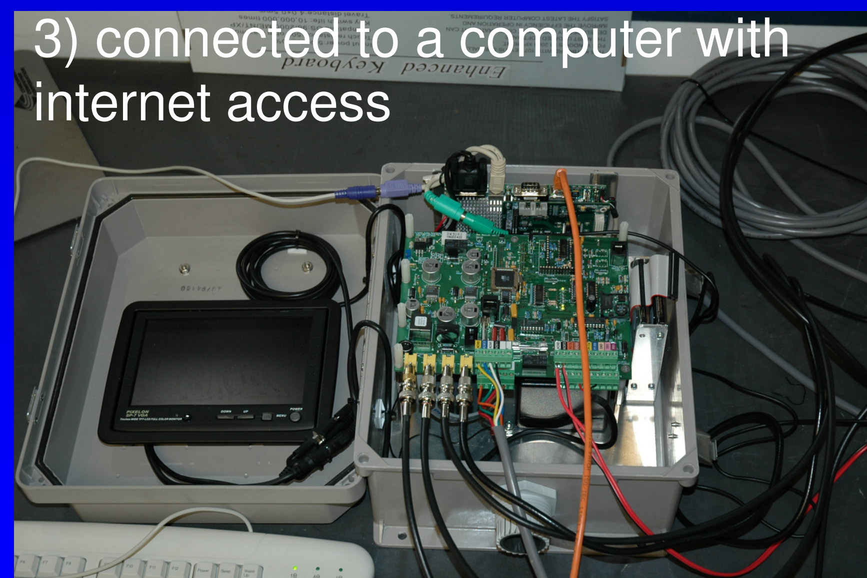
Photo courtesy of DNREC

WHAT IS SANDCam?

1) A collection of video cameras

- There are 7 cameras on the Henlopen hotel
- Imagery is sent to the University of Delaware via the internet for processing

2) located in protective housings



3) connected to a computer with internet access

WHAT SANDCam IS NOT

- SANDCam is not a streaming web surf cam.
- Those cameras can only provide qualitative information
- SANDCam only collects certain imagery products. We then transform the images to a real world coordinate system yielding **quantitative** information

APPLICATION OF SANDCam TO REHOBOTH BEACH

- Video system installation Began on March 25, 2006
- Total of 7 cameras
- Hourly daylight imagery plus pixel time series
- Web-dissemination at sandcam.coastal.udel.edu

Graduate student, Nat Pearre, on the roof of the Henlopen Hotel during camera installation http://sandcam.coastal.udel.edu

IMAGERY PRODUCTS

Apr 29 06 17:32:46 Cam7 3008 images averaged over 10.minutes, 5.01 frames/sec.

Apr 29 06 17:32:46 Cam7 Variance Image: 3008 images over 10.minutes, 5.01 frames

Snapshot

- Analogous to image taken from still camera
- General ‘feel’ of surf conditions (large or small waves etc.)

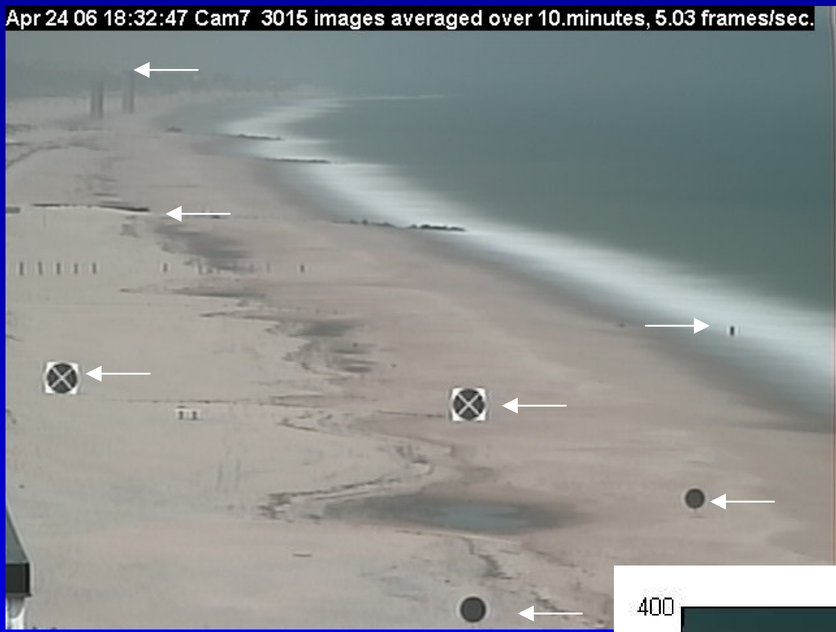
Timex

- Average image intensity over 10 minutes
- Bright features correspond to waves preferentially breaking in common region

Variance

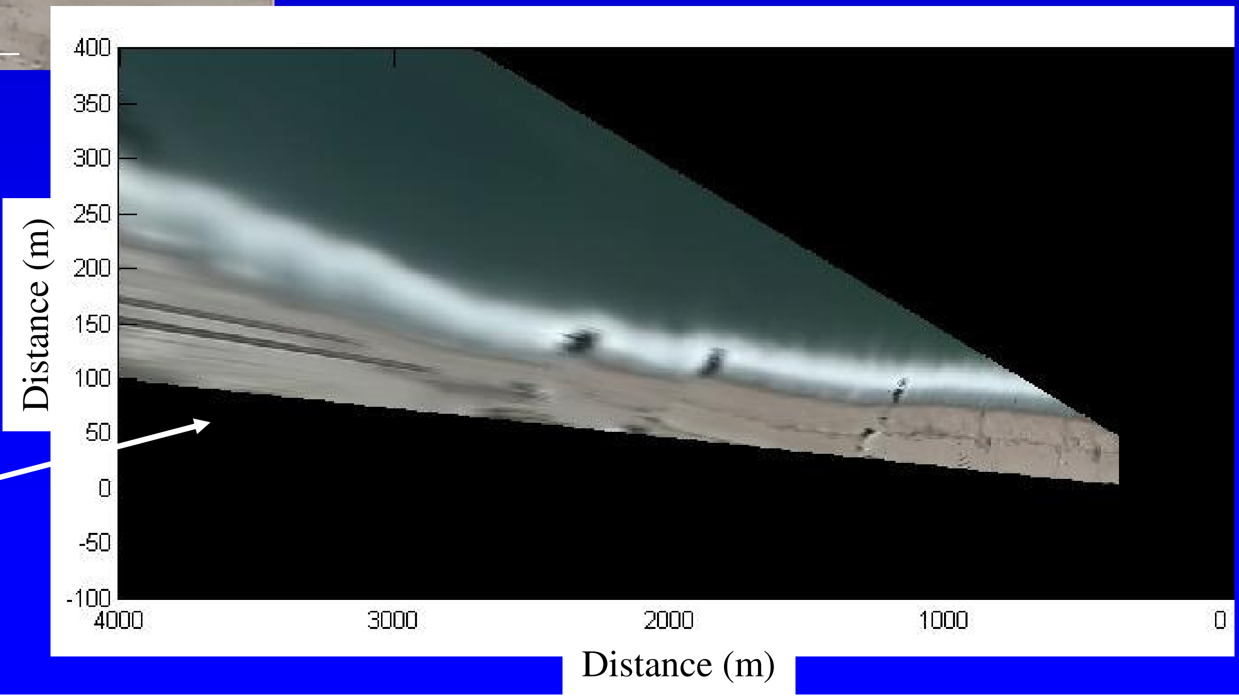
- Variability in image intensity over 10 minutes
- Bright features correspond to ‘high’ variability
- Beach dark → no variability

IMAGE TRANSFORMATION



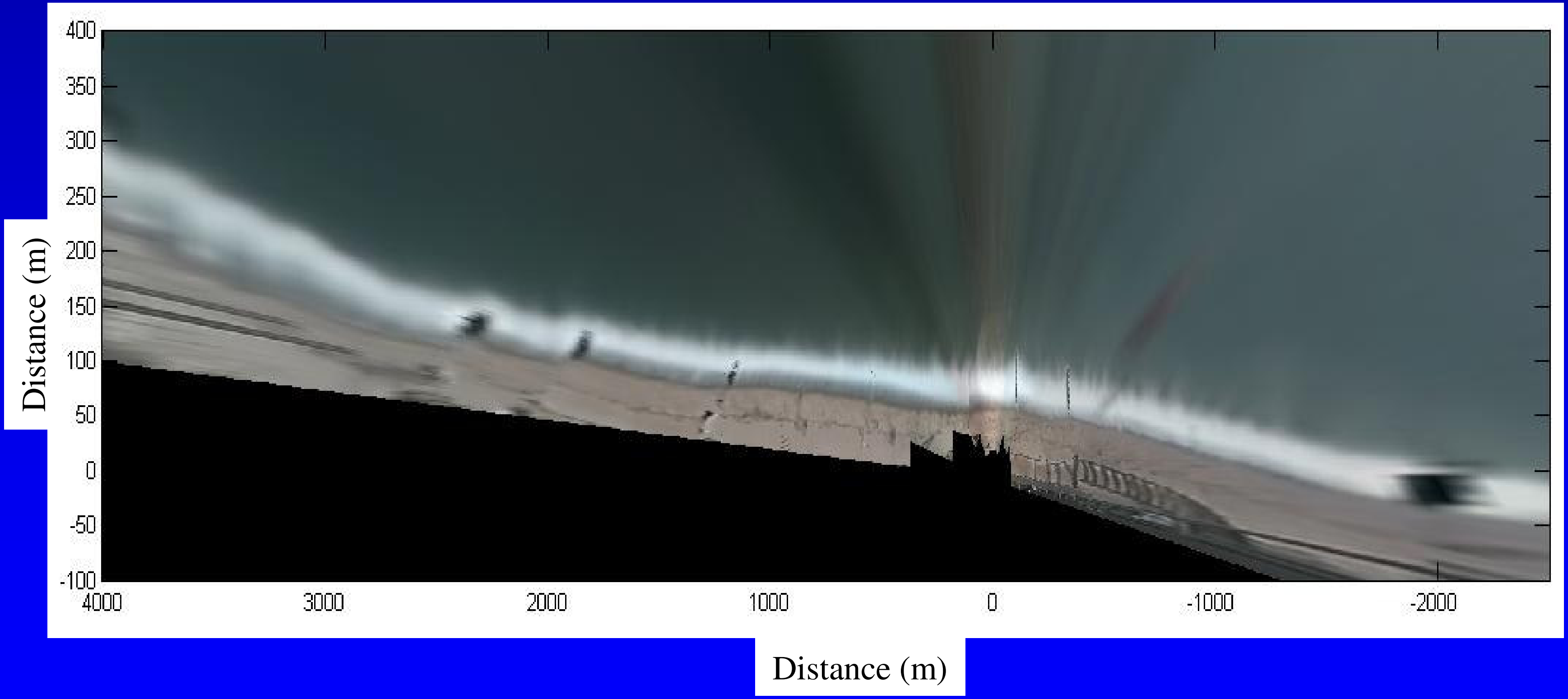
Survey several
Ground Control Points

Convert image from 2D to 3D real world coordinates



MERGED IMAGE

The previous slide showed one camera's transformation. The image below shows the "stitched" image from all seven individual cameras



Imaging over 6 km of coastline from the Henlopen Hotel.

AUTOMATED SHORELINE IDENTIFICATION

Computer algorithms have been developed to detect the shoreline from merged imagery allowing us to perform statistical analyses and determine trends in shoreline evolution

SPECIFIC INTERESTS

- Nourishment monitoring
- Comparing nourishment variability to theory
- Temporal and spatial variability in the shoreline location
- Effect of emerging groins on altering shoreline

Image showing the four north looking cameras. Spikes on camera housings alleviate bird landings that can change camera angle and orientation.

COLLABORATIVE EFFORT

DNREC Division of Soil & Water Conservation

University of Delaware

Center for Applied Coastal Research

Henlopen Hotel

Coastal Imaging Lab
Oregon State University

Center for Applied Coastal Research

University of Delaware

Please visit sandam.coastal.udel.edu to view hourly updated imagery and imagery products

Questions regarding this project should be directed to:

Dr. Jack Puleo
Center for Applied Coastal Research
University of Delaware
302-831-2440, Email: jpuleo@coastal.udel.edu

9.2 Appendix B. Images

Included in this report are the raw images from the Rehoboth Beach SANDCam site. Each disk contains roughly 3 months of raw, time-stamped imagery in daily directories.

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