Video Metric Systems™

from NorthWest Research Associates, Inc.

Applications of the Argus Technology for Coastal Zone Management and Engineering

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Argus Remote Video Monitoring

Argus Beach Monitoring Stations (ABMS) provide continuous, *quantitative* information on shoreline migration, beach erosion, and nearshore processes.

- Shoreline location
- Beach width, area change
- Beach profiles, volume changes
- Pre-storm, post-storm characterization
- Offshore bar location, morphology
- Times series, trends analyses

Objectives

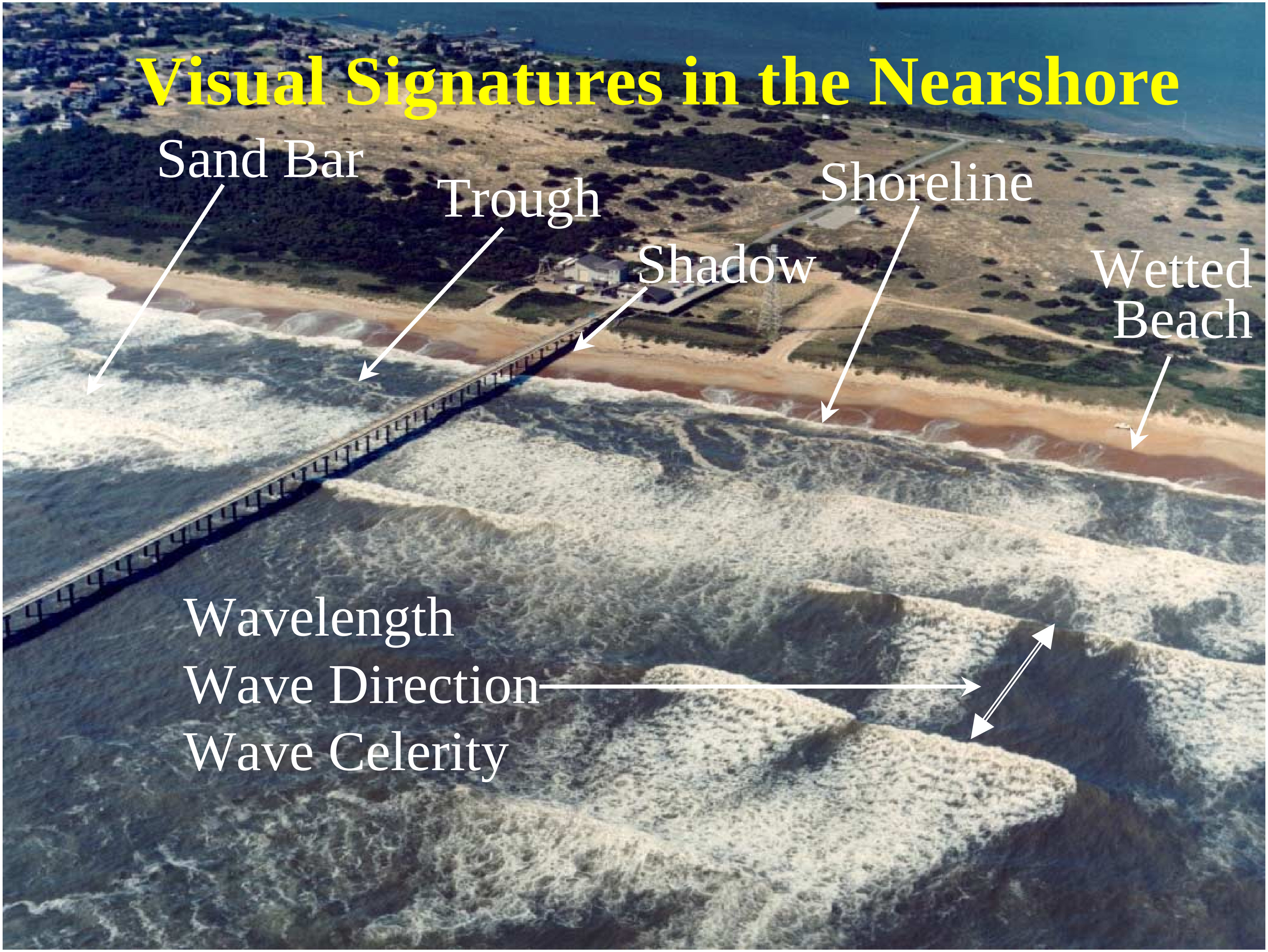
- Describe the Argus technology
- Demonstrate capabilities through examples
- Discuss roles and responsibilities
- Summarize what we've learned about user requirements

Outline

- Overview of the technology
- Data types
- System performance
- Case studies
- New developments
- Organizations and responsibilities
- Steps in an Argus project
- Results from user survey

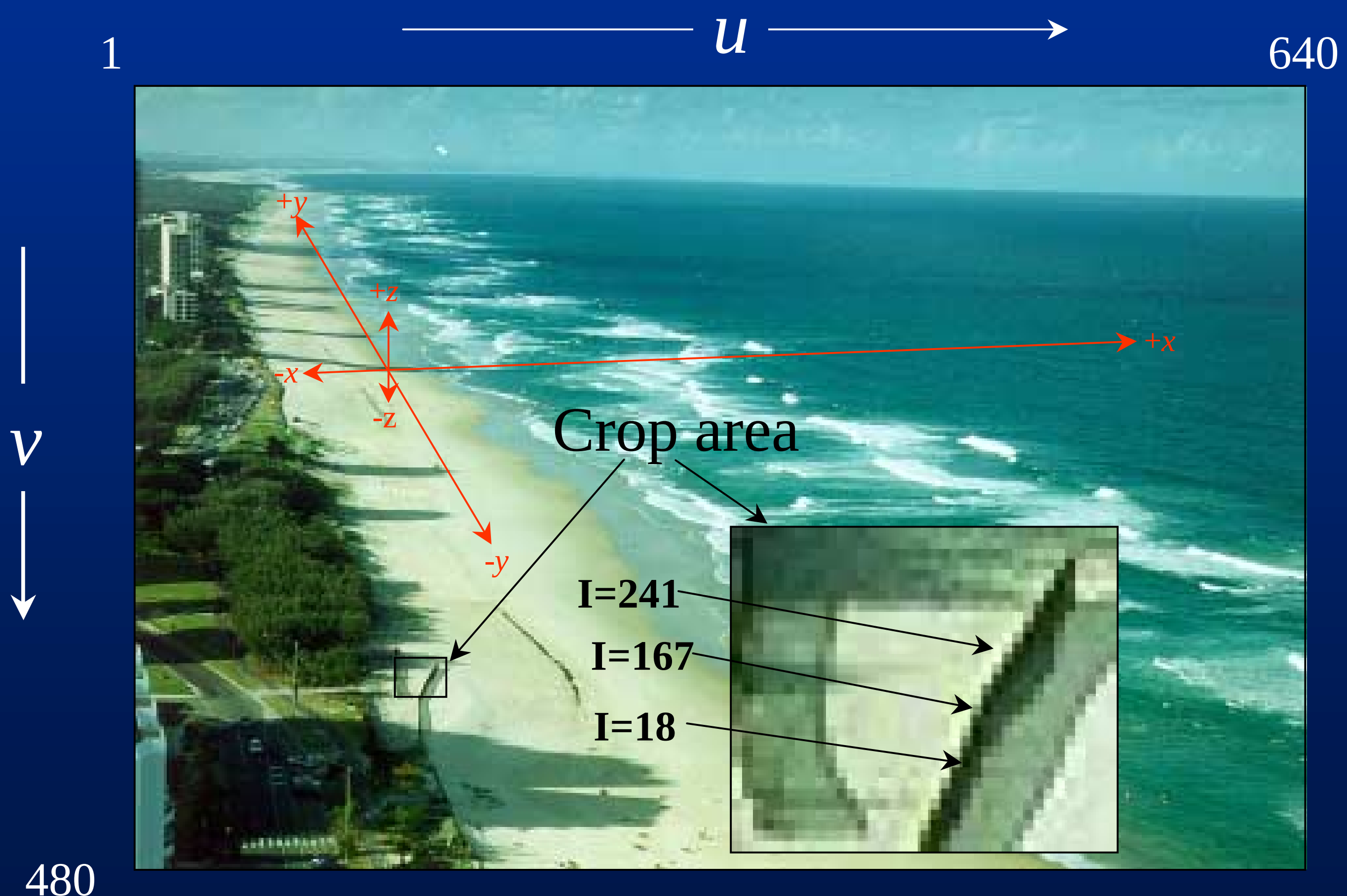
The Basis for Video Monitoring

- We want to identify visual signatures of the features and processes we are interested in
- We need to determine where these signatures are located in the real world
- We need methods (algorithms) to identify and track these features in space and time
- We want these processes to be automated and easy to implement


Visual Signatures in the Nearshore
Sand Bar
Trough
Shadow
Shoreline
Wetted
Beach
Wavelength
Wave Direction
Wave Celerity

Basics of Digital Imagery

An image consists of a 640 (u) x 480 (v) matrix of pixel intensity (I) values (0-255).*



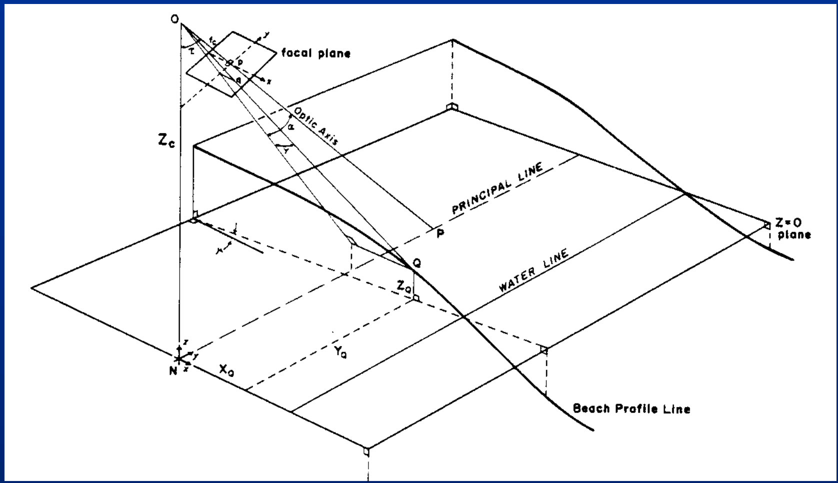
* Grayscale values; color images are recorded as pixel intensity in red, green, and blue: I_{RGB} = (0-255, 0-255, 0-255).

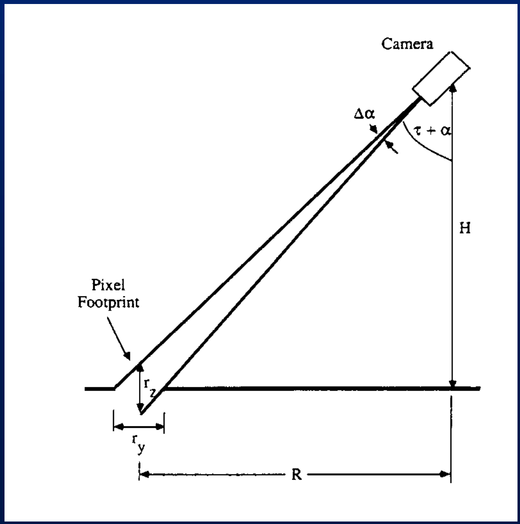
Photogrammetry

- We convert from image (u,v) coordinates to world (x,y,z) coordinate using photogrammetry
- Problem is going from 2 knowns (u,v) to 3 unknowns (x,y,z):
  - To solve for (x,y), constrain $z = z_{tide}$
  - To solve for (z), constrain x (or y), e.g., via calculated position of a shadow line on a beach
- To maintain accuracy of geometry solutions, we need a few ground control points (GCP)

Overview of the Technology

- High resolution video cameras look down on a beach at oblique angles
- SGI™ imaging system produces snapshot, time exposure, and variance images with 640 x 480 pixel resolution
- Geometry solutions are solved to map pixel coordinates (*u*,*v*) into world (*x*,*y*,*z*) coordinates (photogrammetry)
- Pixel data are merged and rectified into Cartesian coordinate system (plan view)
- Analyses of pixel intensity over time identify and track key nearshore features, processes



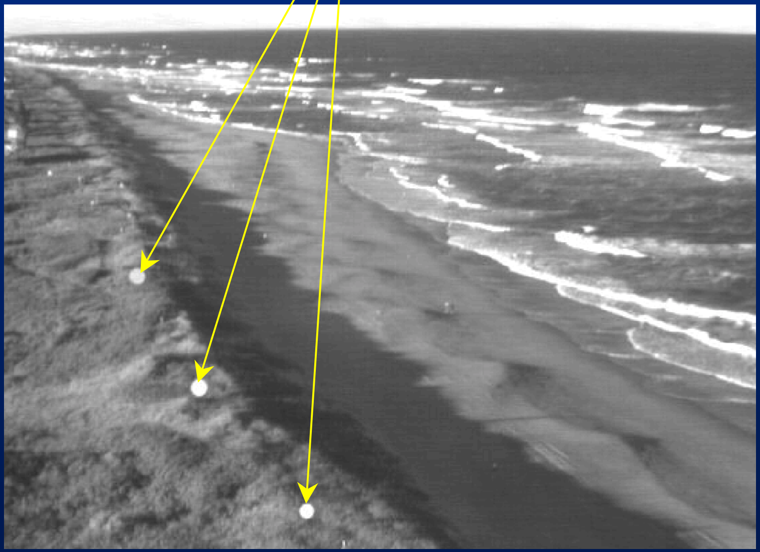


Types of Video Data

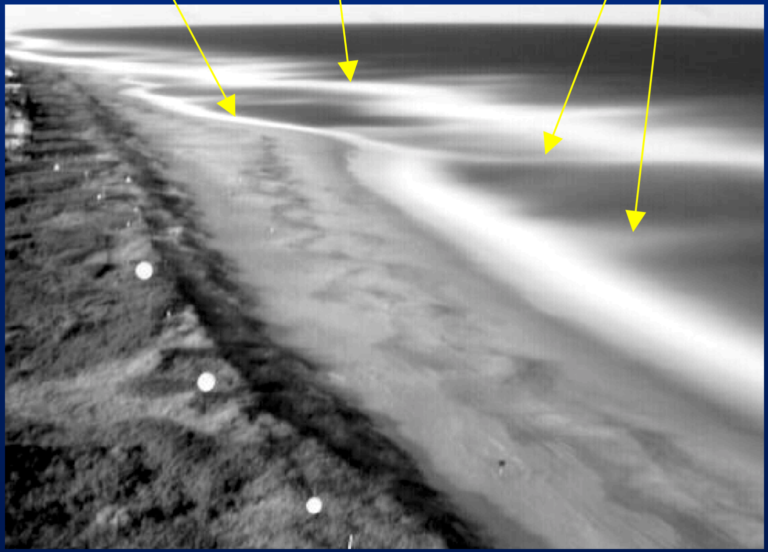
- "Snap shot" images
- Digitally averaged time exposures ("timex"):
  - Mean intensity (nominally 10 minute average)
  - Intensity variance (σ_I^2)
- Merged panoramic images (multiple cameras)
- Rectified images
  - Plan view in Cartesian coordinates
- Intensity along transects ("time stacks")
- Individual pixel intensity

Time Exposure Images

Digitally averaging image intensity removes short term variability ("visual noise") and allows features in which we're interested to be revealed.



"Snap Shot" Image



10 minute
Time Exposure

Mean and Variance Images

In variance (σ_I^2) images, dark areas indicate little change in pixel intensity during the averaging period, bright areas the opposite, revealing details of features and providing measurements of range (e.g., run-up) and uncertainty.

10-min Timex

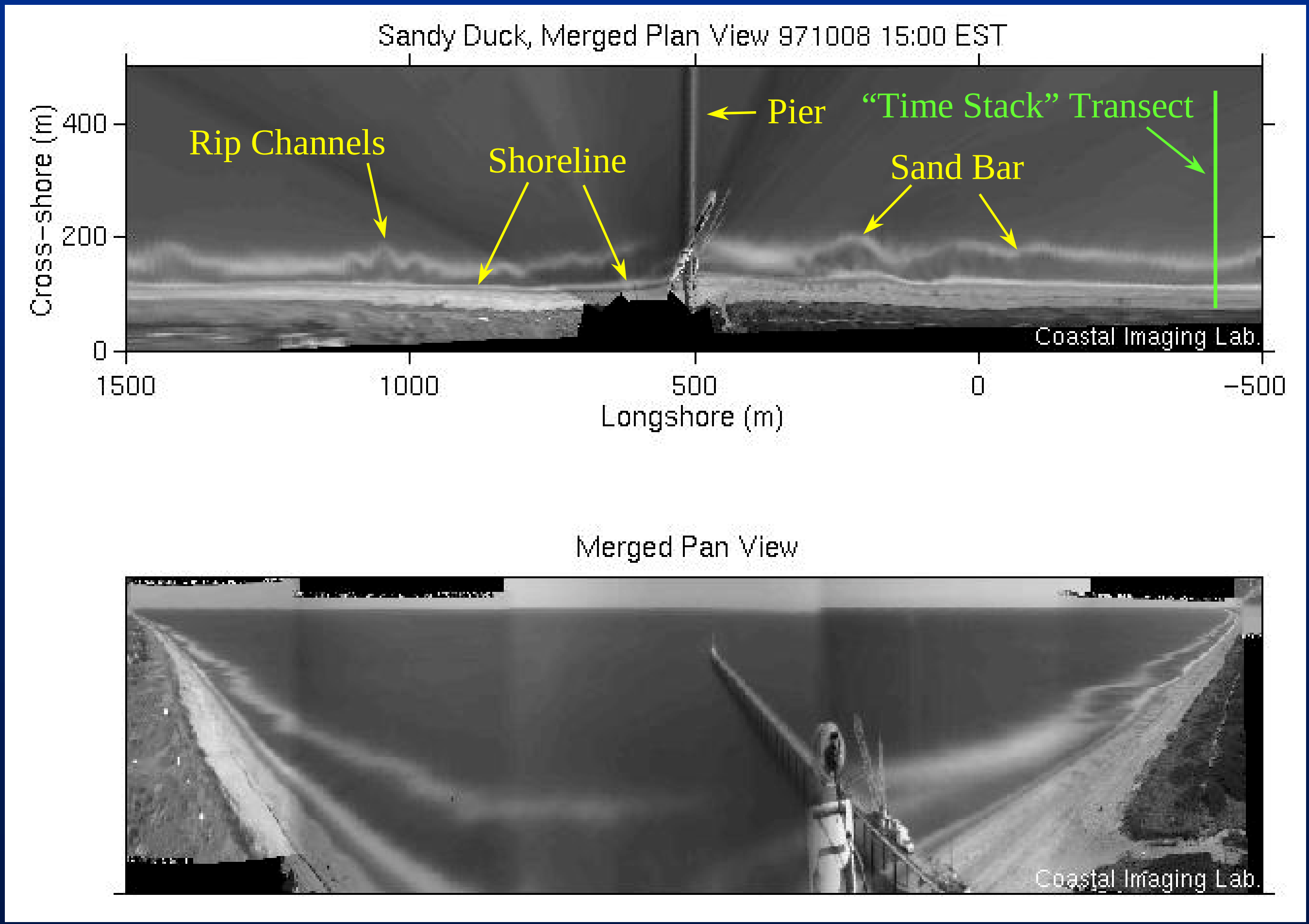
10-min Variance

Cusps

Cusps

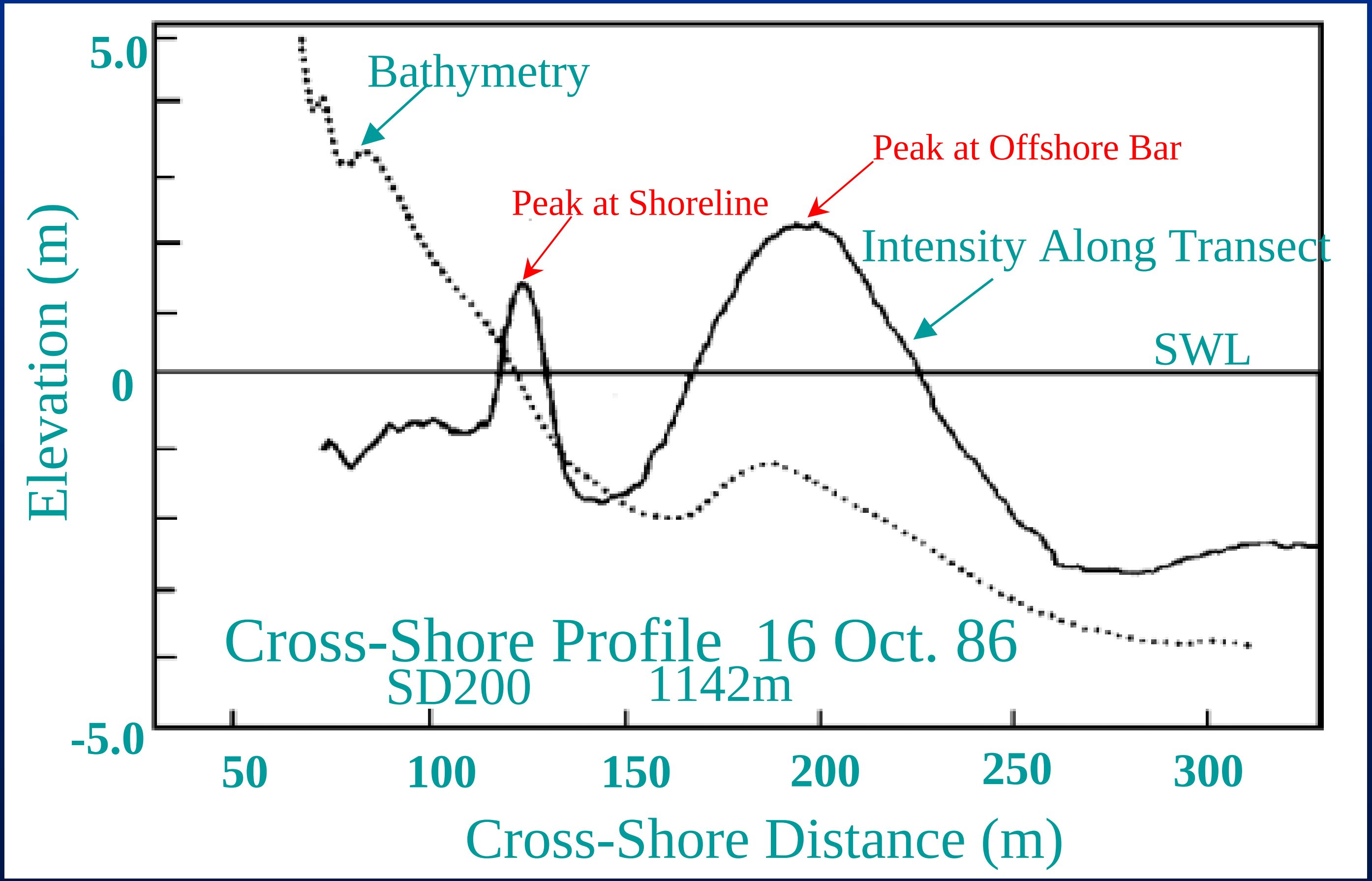
Image Merging and Rectification

Data from five cameras are shown in these figures.



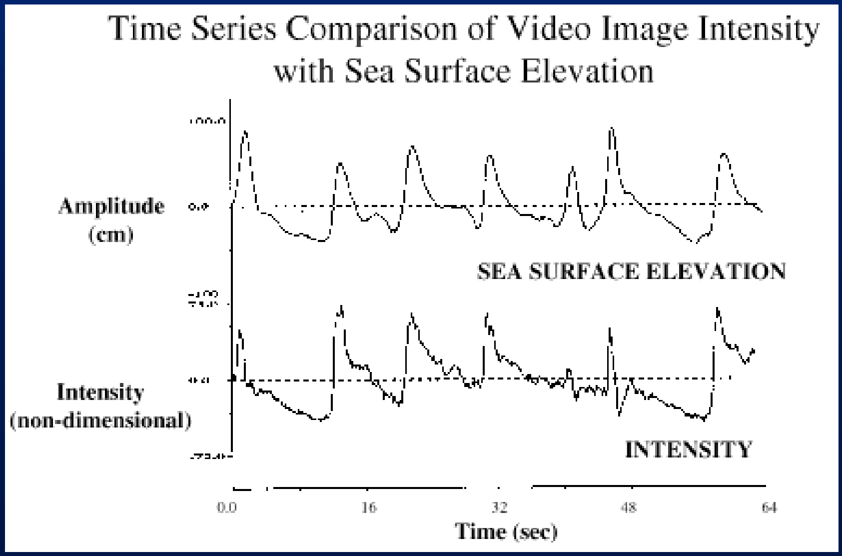
Ground Truth of Timex Images

Comparison of transect intensity data with measured bathymetry at Duck, NC (Lippmann and Holman, 1989)



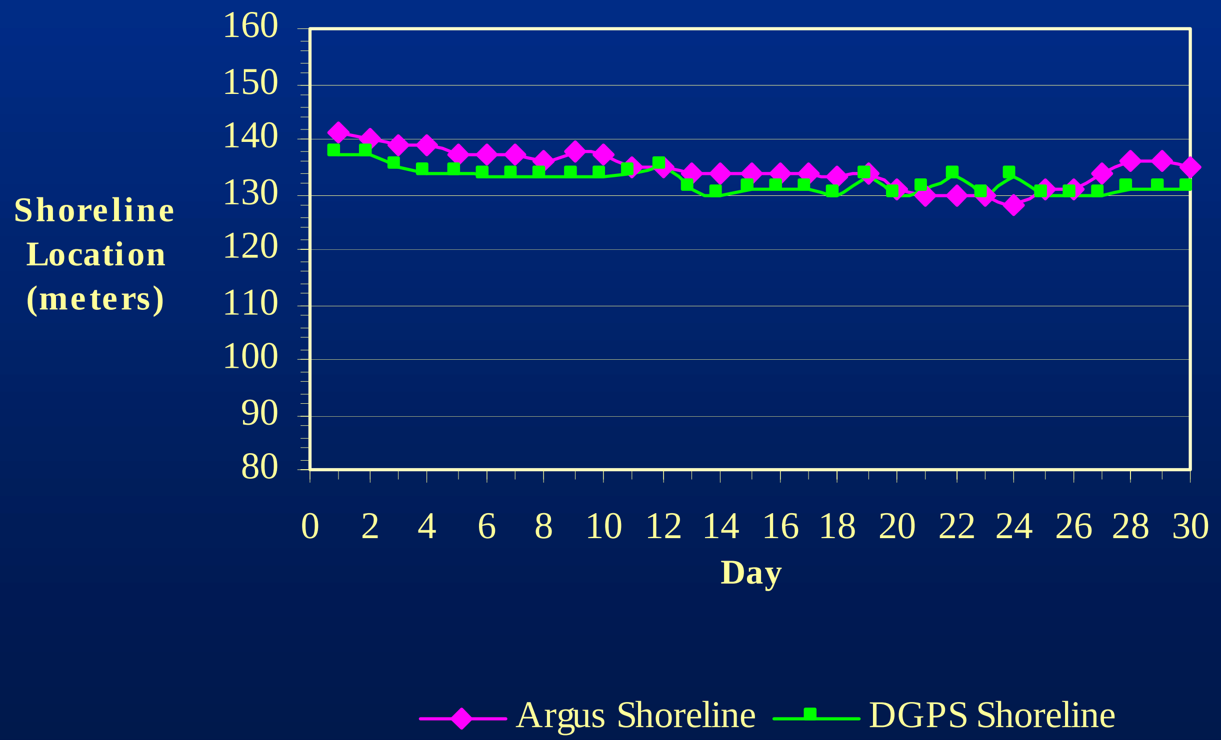
Pixel Intensity Time Series

- Pixels provide “sensors” for visual signatures of nearshore features
- High frequency data collected at pixel sensor located above a submerged pressure sensor at Duck, NC 02/97
- Intensity data show good correlation with wave front passage
- One application of this technique is to measure wave phase speed and calculate offshore bathymetry (see New Developments)



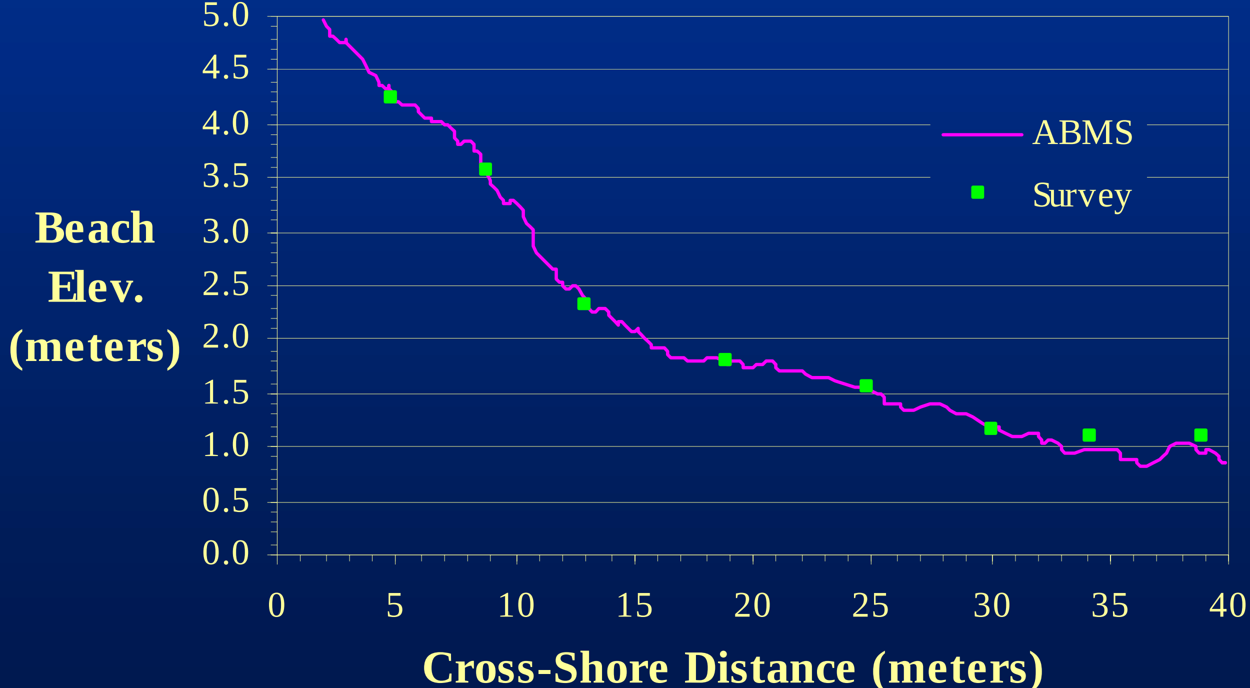
Accuracy of Shoreline Location

Comparison of shoreline location measured by an Argus station and differential GPS (DGPS) at Duck, NC (Plant and Holman, 1997)



Accuracy of Beach Profile

Comparison of profile of beach elevation [*] *measured by an Argus station and traditional survey at Duck, NC (Holman et al., 1991)*



* Vertical elevation is measured by solving for the *z* coordinate of a cross-shore "line in the sand" whose *x* and/or *y* position is known or can be calculated (e.g., shadows).

ABMS Specifications

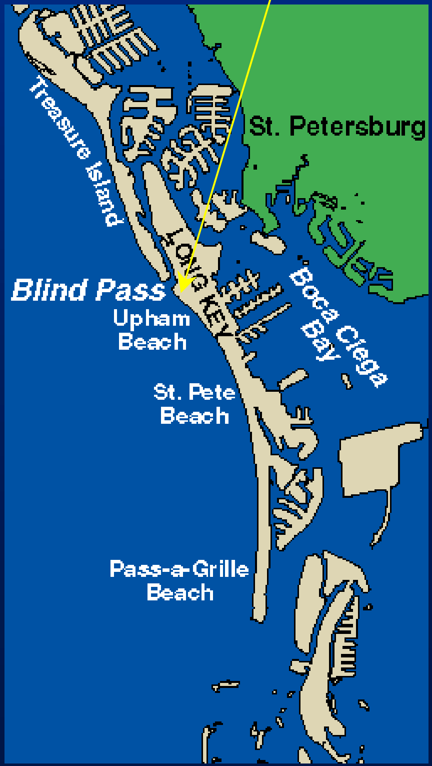
Parameter	Value
Range*	± 40 m to ± 2.5 km
Resolution*	*At 100 meters from station*: x,z = 0.1 m y = 0.5 m *At 1000 meters from station*: x,z = 0.5 m y = 12.5 m
RMS Accuracy	0.35–2.4 m horizontal 10-20 cm vertical
Averaging Interval	10 min. nominal

* Function of camera height, lens focal length

Erosion of a Nourished Beach

- High rates of erosion along Long Key near St. Petersburg, FL necessitate nourishment every 2-3 years
- Each nourishment costs ~$1.5M
- Latest nourishment completed 6/96
- Argus station operated 10/96 - 04/98 to study morphology of this beach

Upham Beach Nourishment



View from roof of condominium where Argus station was installed.

Before

North

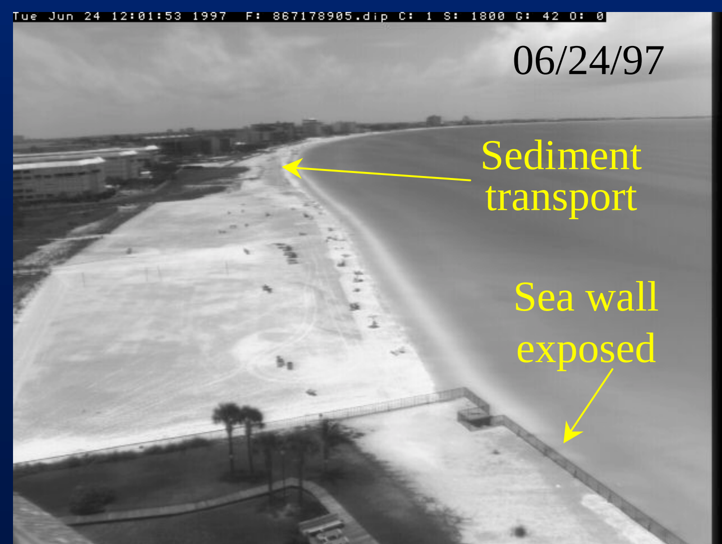
South

After

North

South

Beach Nourishment Change Sequence



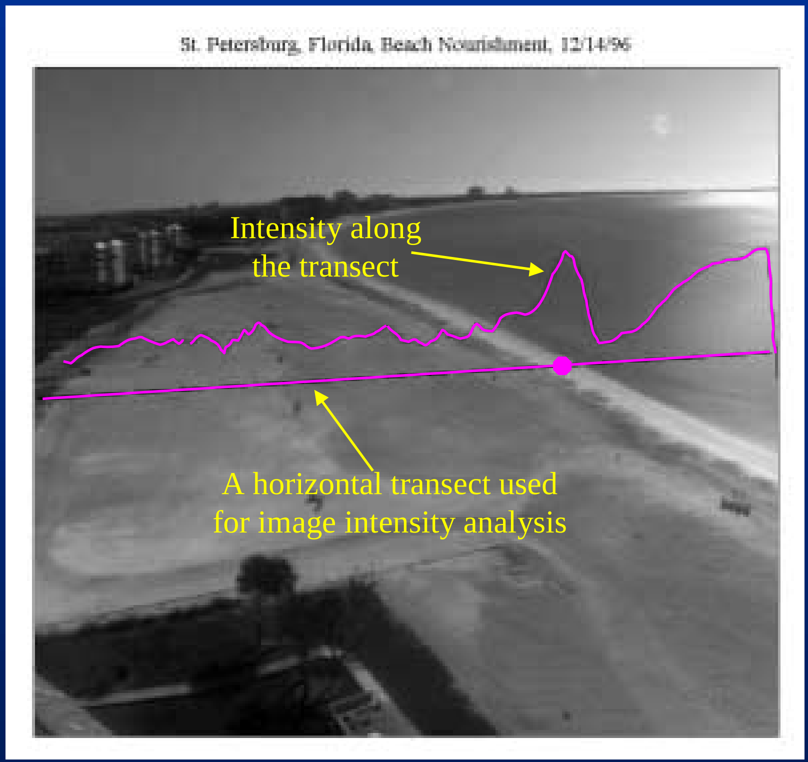
Beach Nourishment Change Sequence

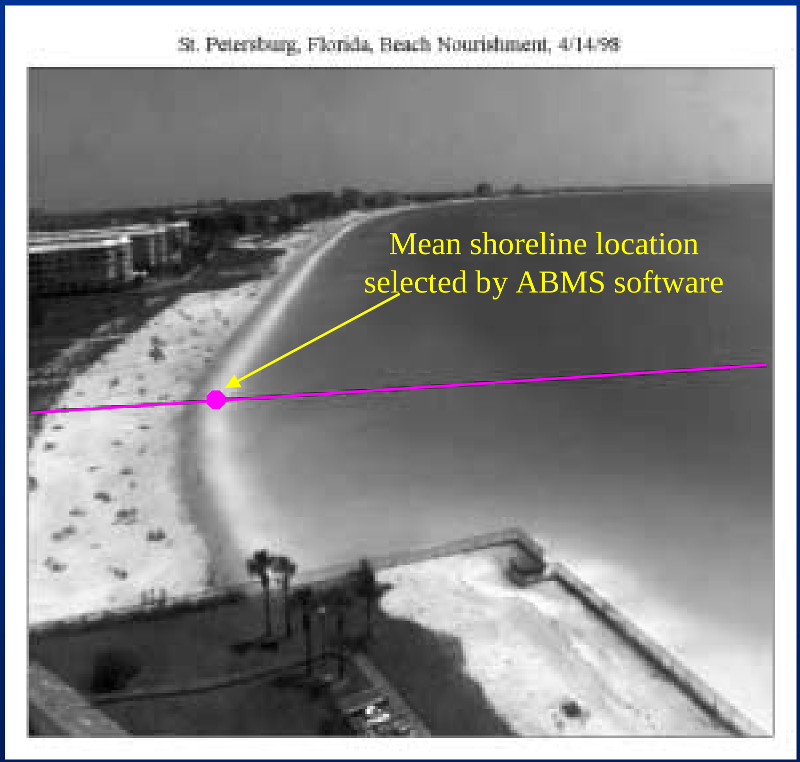
Upham Beach Movie

- Timex images collected at noon (EDT) each day 10/19/96 - 04/14/98
- Movie runs at 6 frames (days)/second
- Things to look for:
  - Erosion in the near field
  - Accretion in the far field
  - Higher rate of loss in winter of ‘97-’98 (El Nino?)
  - Episodic storm impacts (note especially 1/27-2/12 ‘98, but don’t get fooled by missing data)

Run Upham Beach Movie

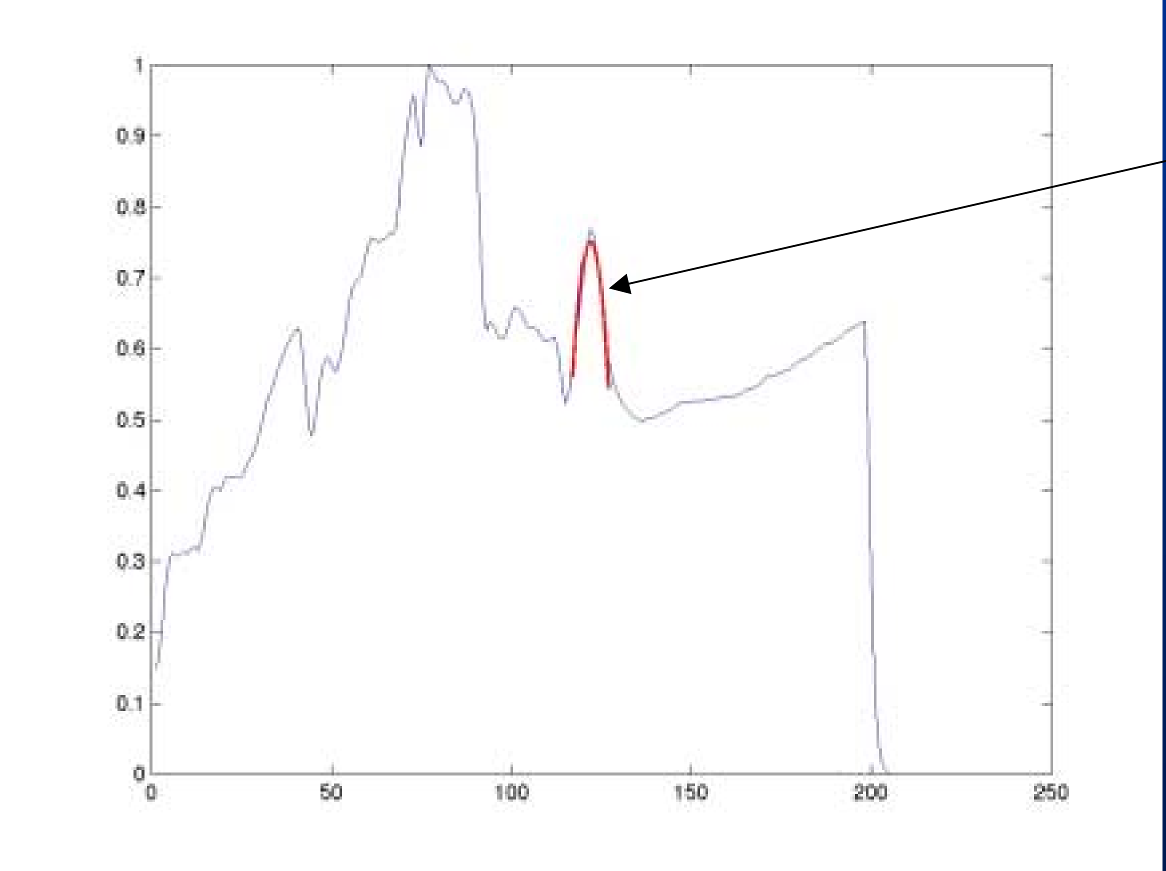
Analysis of Shoreline Retreat





- Specify transect location(s)
- Identify mean shoreline from peak in timex intensity at shore break (variance imagery shows range of run-up)
- Repeat for all hours/days of interest

Shoreline Position Estimation

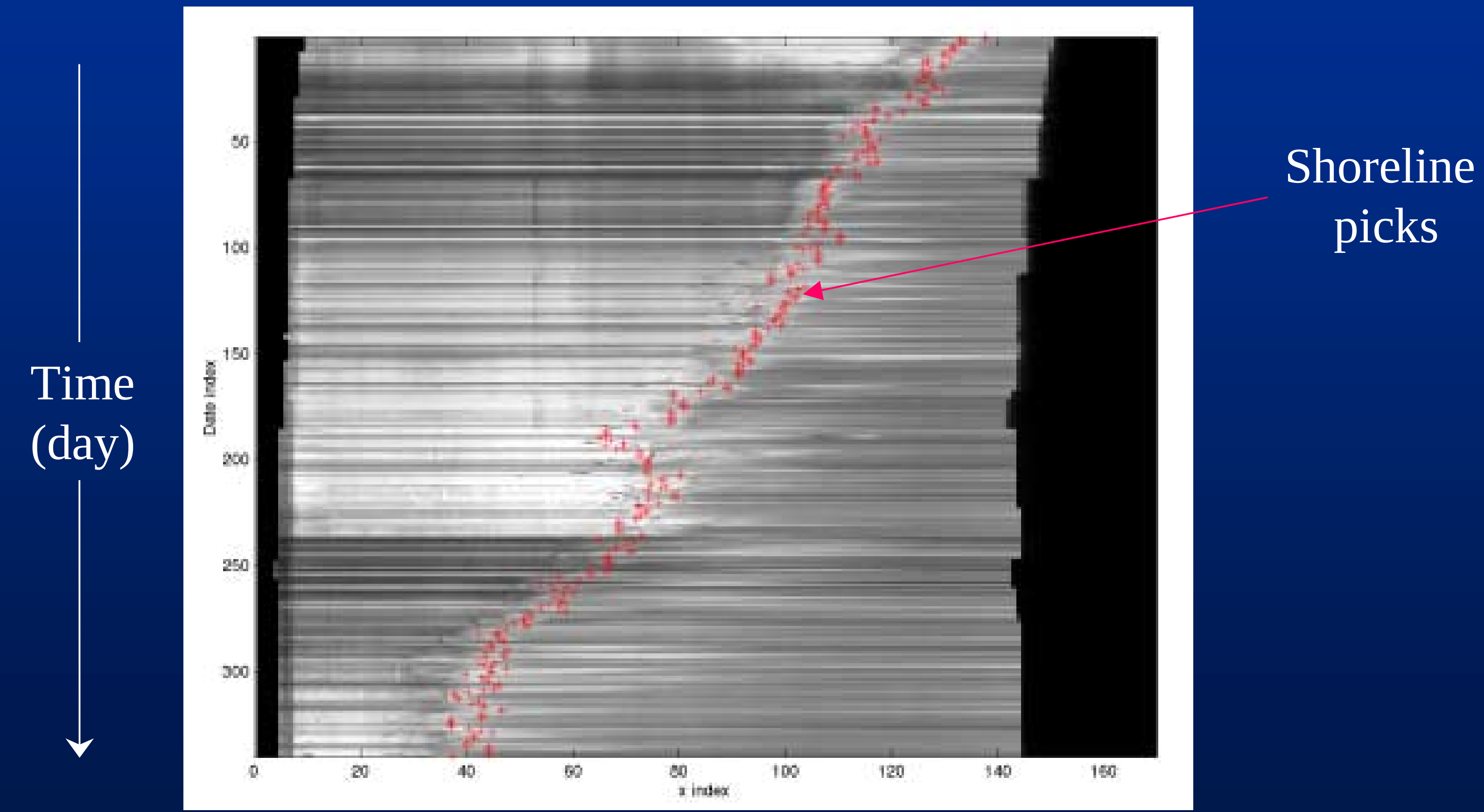


Local parabolic fit

Example non-dimensional intensity transect

Time Stack Data

This time stack shows cross-shore image intensity along a transect as a function of time.

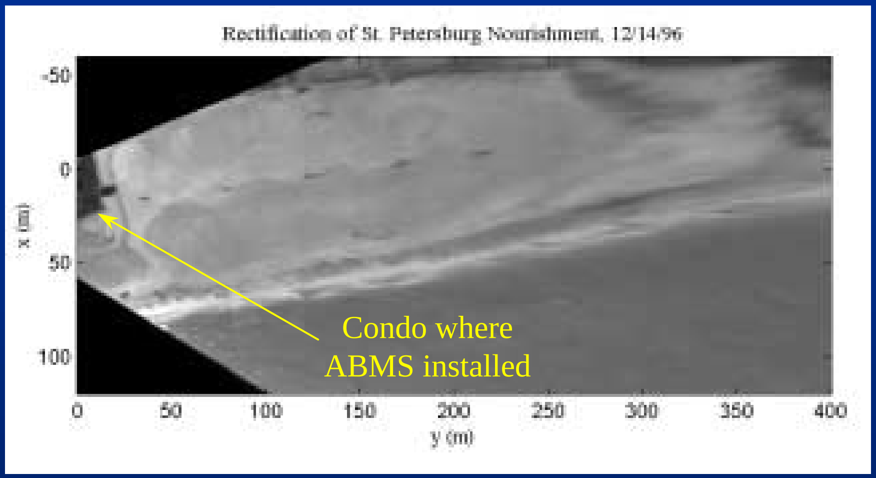


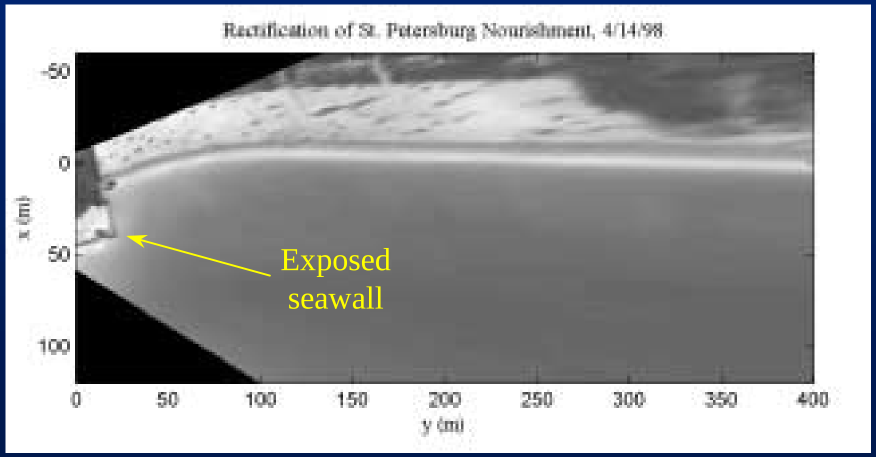
Cross-Shore (x) Distance Along Transect at y = 75 m

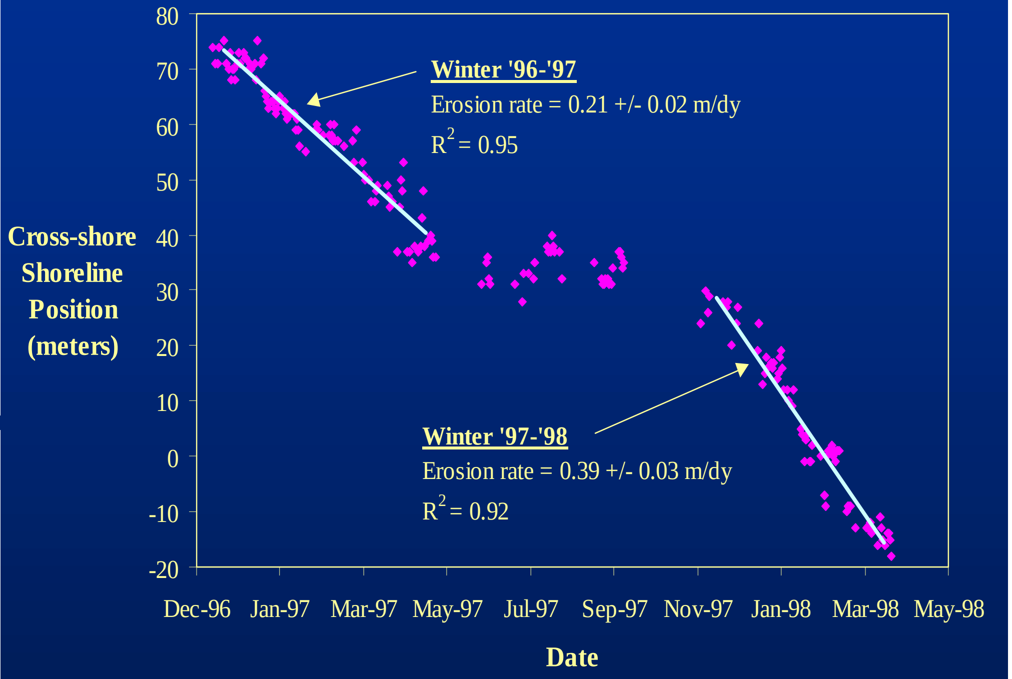
Shoreline Migration

Retreat of the shoreline of a nourished beach near St. Petersburg, FL measured by an Argus Beach Monitoring Station

Trends Analysis



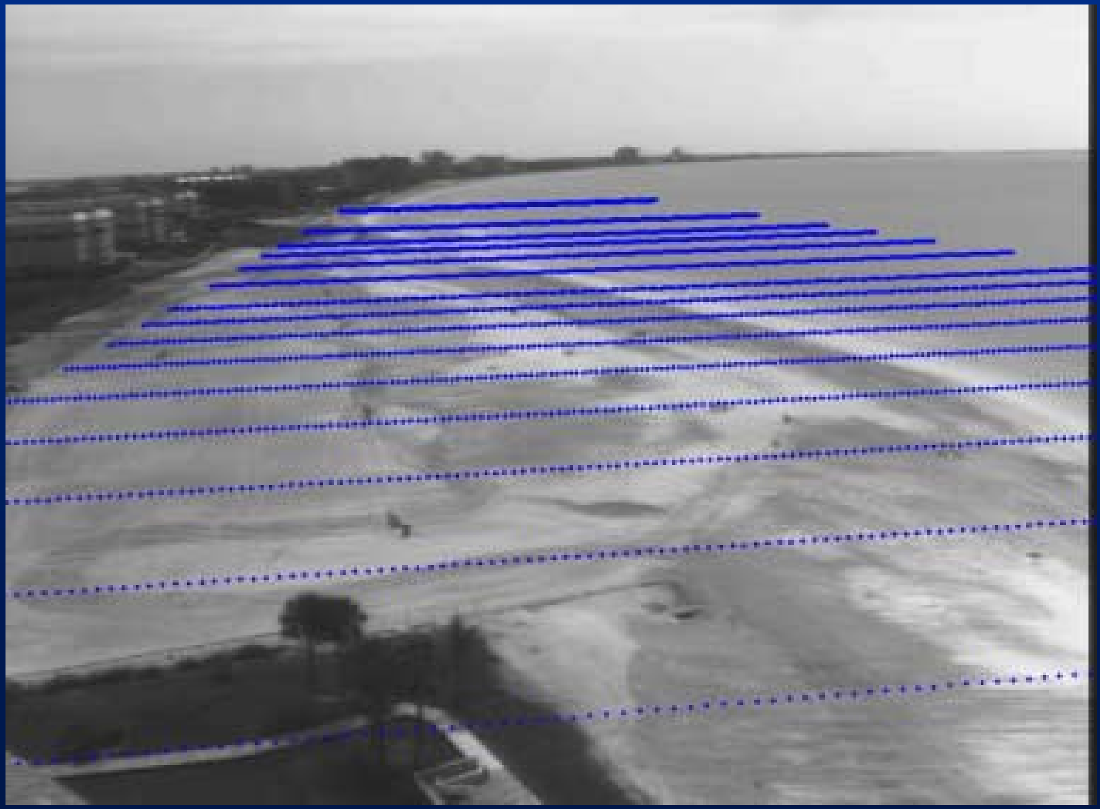




Traditional spot surveys might miss trends, catch the wrong phase of the seasonal erosional cycle, and/or fail to capture episodic changes.

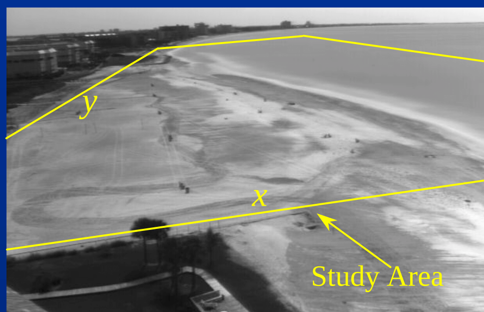
Image Sampling Scheme

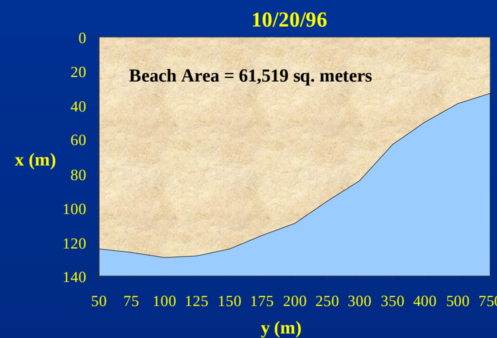
Use multiple transects to map changes in longshore shoreline location, beach area. If vertical profiles are measured (they weren't in this case), volume can be calculated.

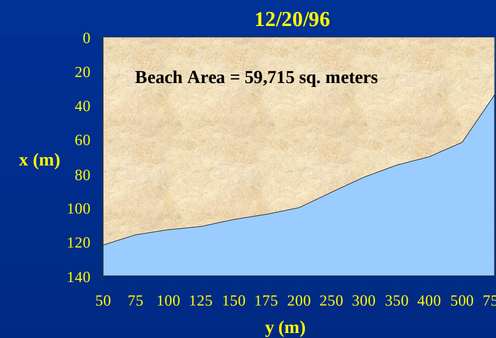


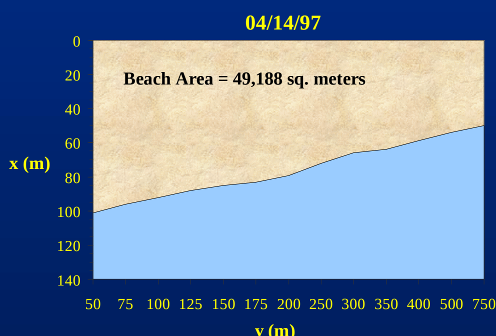
Shoreline and Area Change

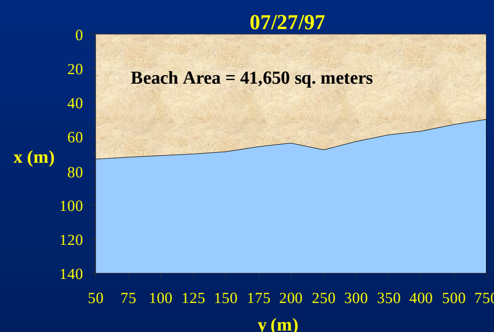
Oct. 1996

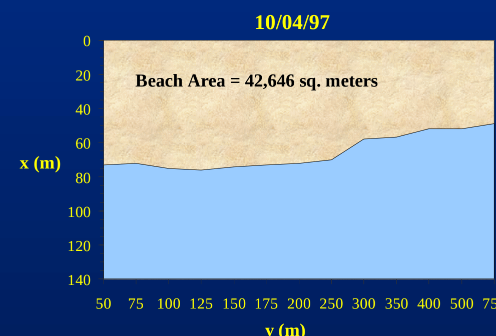


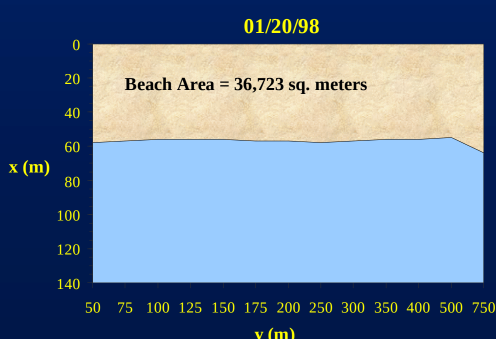


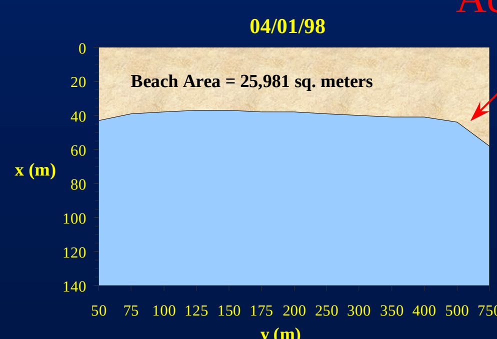












Accreted Area

Apr. 1998

Palm Beach, Australia

- Since 1995, 2 cameras
- Intermediate beach
- 1 m tide range
- H ~ 1.5 m, T ~ 10 s


ARGUS2.0 timex palmetto Fri Jun 19
:00:06 1998 EST-10 F:
Palm Beach, Australia
This image is referred to as a “daytimex,” where a full day of intensity data are averaged. Daytimex’s reveal mean locations of nearshore features and are useful for creating movies showing evolution of features.
Rip Currents
Gamma: 1.40 Files: 11 Lbox: 20 600 50 450
898246807.Fri.Jun.19_09:00:07.GMT.1998.palmetto.c1.timex.pnm

Rip Currents

A single weekend in Australia

UP TO 20% OFF ALL PLANTS
GARDEN BARN
9905 3382

The Manly Daily
SERVING THE PENINSULA SINCE 1906

John Rowles live in concert!
25th January
Dinner & Show

188 rescued

Holiday swims turn to drama

Be wary of land council pledges, says MP

Palm Beach Movie

- Rectified daytimex images from Palm Beach, Australia 02/96 - 12/96
- Movie runs at 6 frames (days)/second
- Things to look for:
  - Rip channel development, translation
  - Bar development
  - Longshore displacement
  - Storm impacts

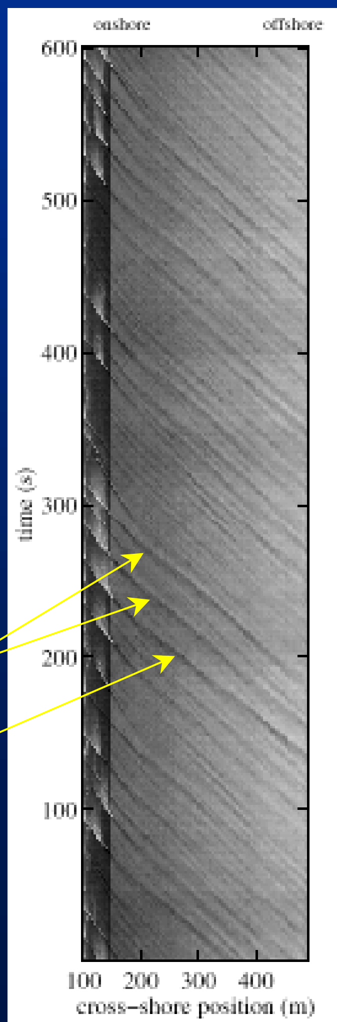
Run Palm Beach Movie

New Developments

- Wave phase speed, direction and their relationship to nearshore bathymetry
- Visibility (turbidity)
- Traffic counting, transportation impacts
- Beach usage
- Sea turtle nesting (with IR cameras)

Argus Bathymetry*

Time stack of cross-shore pixel intensity

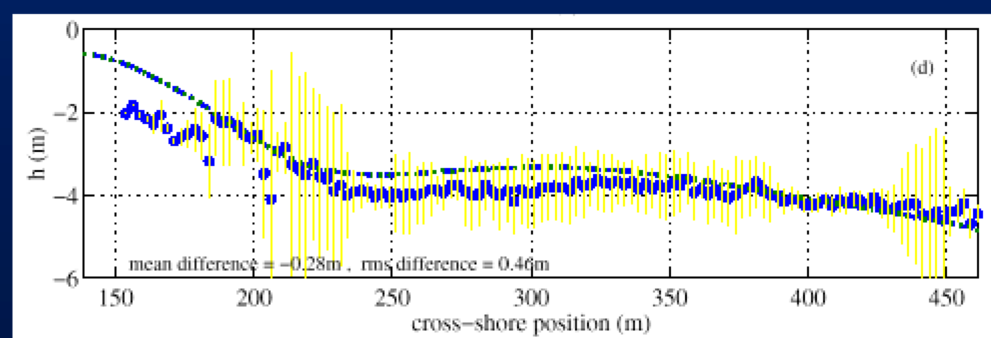


Wave fronts

Slope ∝ *c*

- High frequency video sampling used to measure wave phase speed (*c*) and direction
- Offshore bathymetry calculated from relationship between *c* and depth (*h*) expressed in shallow water wave equation
- Argus data compared to measurements made by the "CRAB" at Duck, NC during SandyDuck experiment, Oct. 1997

Argus bathymetry vs. CRAB



** Data courtesy of Hillary Stockdon (USGS) and Rob Holman (OSU)*

Roles and Responsibilities

- NorthWest Research Associates, Inc. (www.nwra.com)
  - ABMS commercial applications in North America*
  - Ongoing ABMS product development and research
  - Supporting research and services:
    - Coastal oceanography, meteorology, earth sciences
    - Measurements, data analysis, modeling
- Oregon State University (http://cil-www.oce.orst.edu:8080)
  - Argus created at the Coastal Imaging Laboratory
  - Ongoing techniques and data products development
  - Nearshore research

* *NWRA sub-contracts to North American firms for international projects.*

Roles and Responsibilities (con't)

- USACE (http://www.frf.usace.army.mil/video.html)
  - Coastal Hydraulics Lab, Field Research Facility
  - Applied research, ABMS ground truth comparisons
- USGS (http://coastal.er.usgs.gov/rvm)
  - Coastal and Marine Geology Program
  - Applied research, airborne lidar surveying
- Delft Hydraulics
  - Government-mandated monitoring of the Dutch coastline
  - ABMS commercial applications outside N.A.

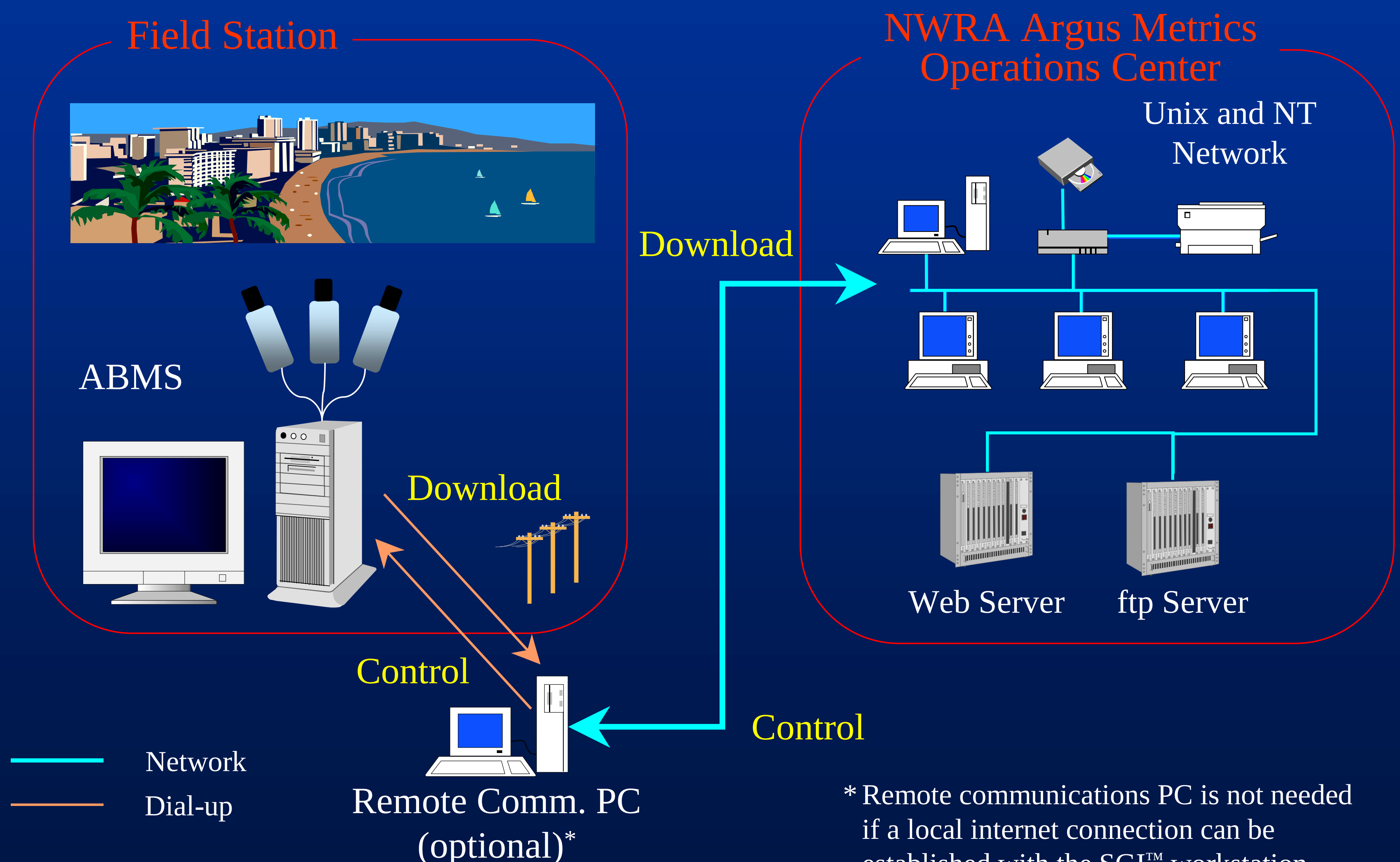
Services Provided by Video Metric Systems™

- Design monitoring programs
- Deploy, operate, and maintain the stations
- Process, quality control, and analyze the data
- Prepare basic and advanced data packages
- Develop information for public outreach (e.g., web page hosting, internet dissemination)
- Provide supporting nearshore oceanographic and meteorological measurements
- Provide supporting R&D

Steps in an Argus Project (1 of 2)

- Preparations:
  - Establish requirements for spatial resolution and range
    - Number of cameras needed, sampling geometry
    - Height is important (e.g., building, tower)
  - Site and equipment preparation, deployment
    - Power, shelter, communications, security, permitting, ...
    - Lens calibration (correct for distortion)
    - Survey ground control points (GCP)
- Routine operations:
  - Continuous data collection, processing
  - Remote data telemetry, monitor station status
  - Routine and emergency maintenance

Data Flow

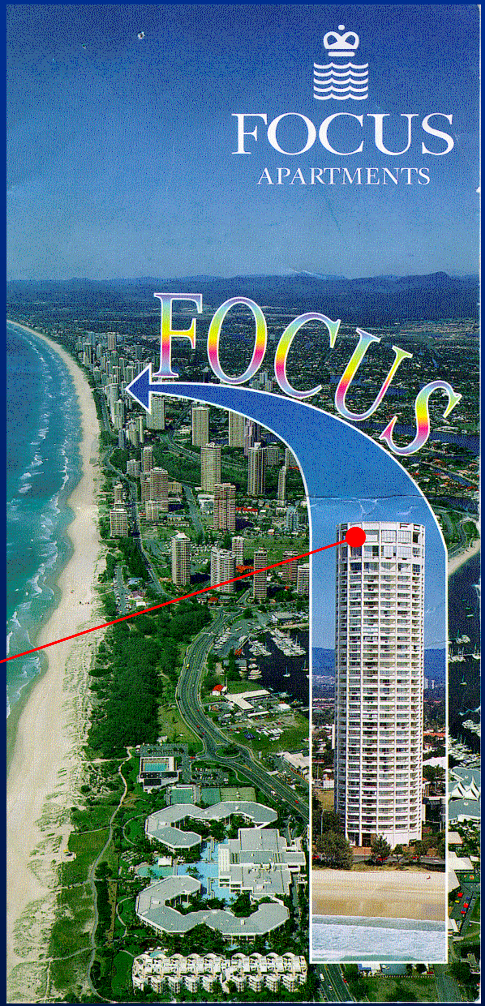


* Remote communications PC is not needed if a local internet connection can be established with the SGI™ workstation.

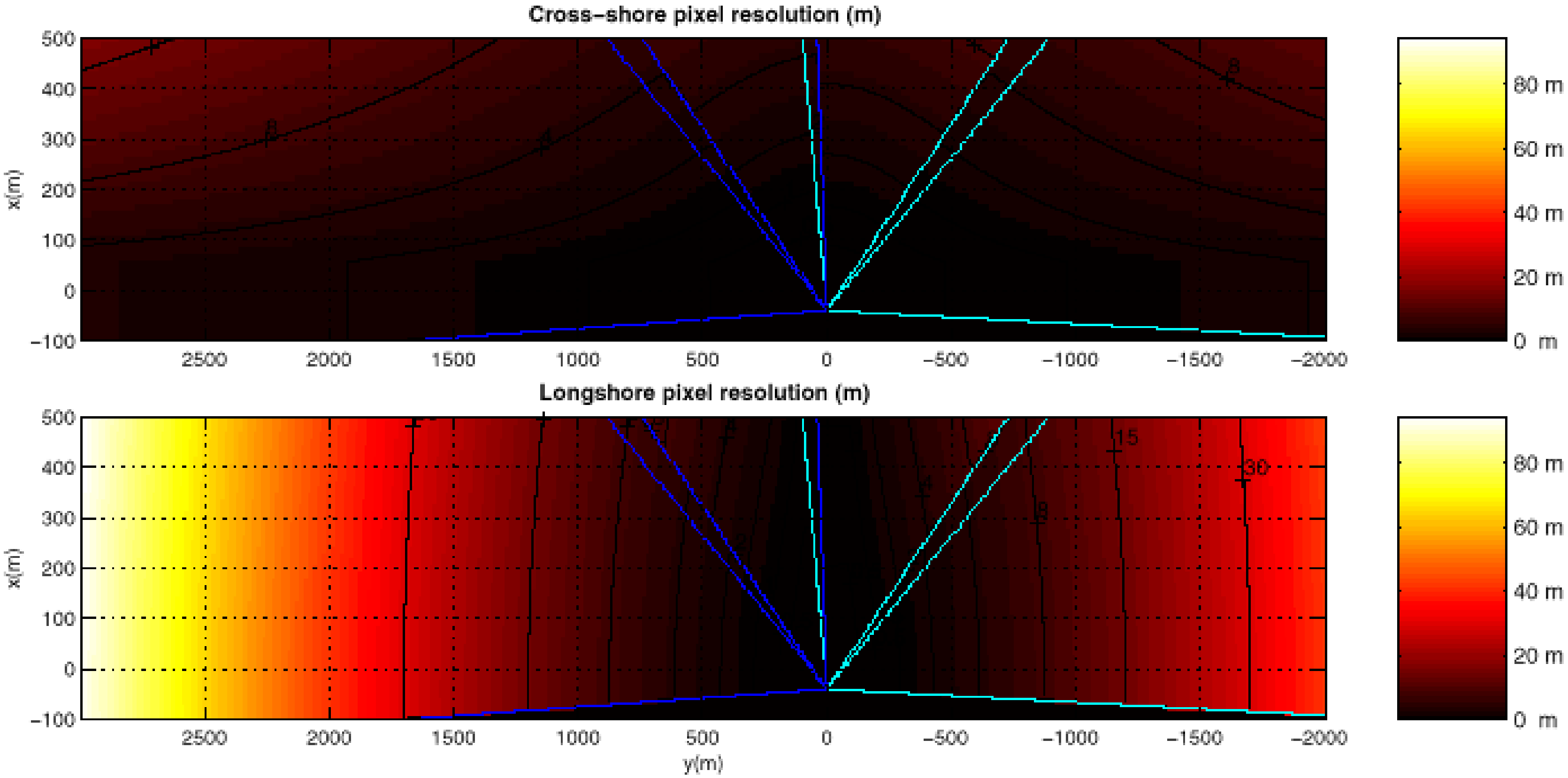
Field Station Design Issues

- Field of view (e.g., 180°)
- Range
- Pixel resolution
- Cover features at specific locations, e.g. structures, horizon, vegetation line
- No. of cameras
- Design support tool
  - Number of cameras
  - Camera orientation
  - Lens focal length

Camera location

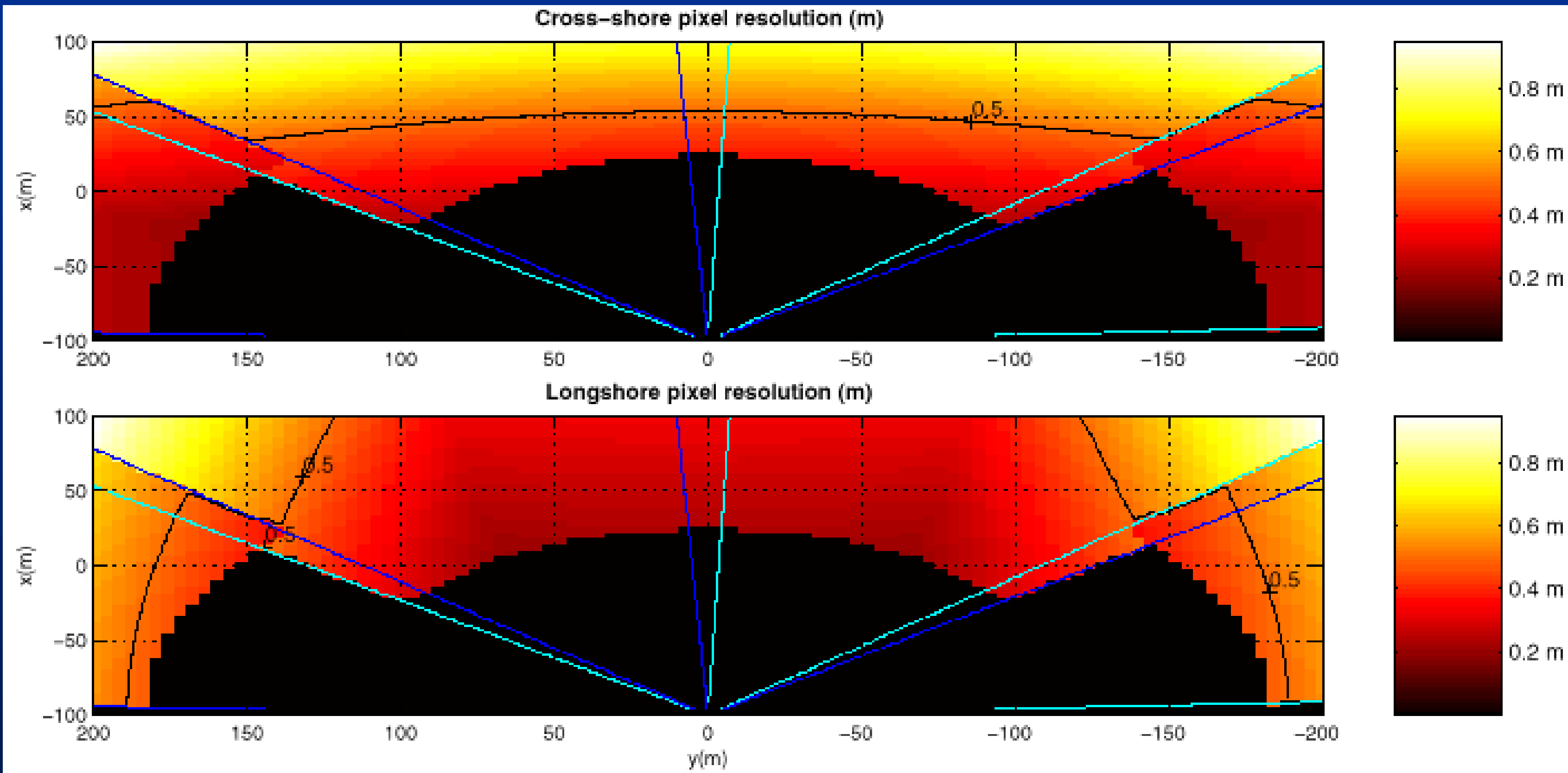


Far Field



Camera layout "goldCoast4camV8"											
cam.	x	y	z	azim	Hfov	tilt	roll	overlap	Flength	azNorth	camName
1	−40	0	100	−72.5	38	77.23	0	0	9	162.5	c1
2	−40	0	100	−24.31	69.1	66.79	0	0.1	4.5	114.31	c2
3	−40	0	100	31.36	54.6	71.66	0	0.1	6	58.64	c3
4	−40	0	100	73.03	38	77.23	0	0.1	9	16.97	c4

Near Field



Camera layout "goldCoast4camV1"											
cam.	x	y	z	azim	Hfov	tilt	roll	overlap	Flength	azNorth	camName
1	−100	0	100	−67.5	40.1	76.53	0	0	8.5	157.5	c1
2	−100	0	100	−24.41	54.6	71.66	0	0.09	6	114.41	c2
3	−100	0	100	25.27	54.6	71.66	0	0.09	6	64.73	c3
4	−100	0	100	68.36	40.1	76.53	0	0.09	8.5	21.64	c4

Steps in an Argus Project (2 of 2)

- Data processing with ABMS MatLab software
  - Prepare basic data package:
    - Quality control images
    - Compute geometry solutions and apply calibrations
    - Produce image archives: merged timex, daytimex, rectified, variance, movies, ...
    - Create data bases of transect, pixel intensity (“time stacks”)
  - Prepare advanced data package:
    - Shoreline features, area, profiles, volume, ...
    - Prepare time series analyses, trends analyses, …
    - Perform final quality control
- Prepare and distribute data deliverables, reports

User Survey

- What are the key problems facing the coastal zone management and engineering communities that Argus stations can help solve?
- What are the high priority data products and services that users want?
- What are user perceptions of the major benefits offered by the technology?

Key Problems

- Quantitative information for tracking long-term (multi-year) shoreline location, migration
  - Support project design, evaluate project performance
  - Where's the beach? Where did the sand go?
- Pre-storm versus post-storm damage assessments
- Analyze long-term trends and identify episodic (short-term) changes, erosional hot-spots
- Sand budgets (area and volume changes)
- Public outreach (education), safety (rip currents)

Data Products and Services

- Shoreline location
- Recreational beach width, area change
- Beach profiles, volume change
- Time series and trends analyses
- Offshore sand bar location, morphology
- Confidence intervals, uncertainties
- Information for public outreach, safety
- Video imagery and movie archives
- Turn-key project design, execution

Benefits

- Obtain cost-effective monitoring for coastal resource planning, management, and evaluation
- Improve accuracy of project designs, monitor construction, evaluate performance more thoroughly
- Characterize pre-storm/post-storm damage more completely and consistently
- Detect important trends, identify "hot spots" and take corrective action sooner
- Receive continuous data with quality comparable to or exceeding traditional survey methods
- Powerful medium to reach the public

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