Coastal Measurements
Field Measurements

1. Shorelines
2. Profiles
3. Planforms

Purpose: to determine present condition and historical change
Historical Change
Examples

1. Shoreline recession
2. Impacts of coastal structures
3. Filling of navigational channels and harbors
Coastal Surveys

Soundings from ships using lead lines and now fathometers

Need tidal correction in shallow water

NOS bathymetric charts

Ask Joe how the Baltimore District does it
NOAA produces and maintains a suite of nautical charts that cover the coastal waters of the U.S. and its territories. NOAA's charts are available in a variety of formats, including:

- Traditional paper charts
- Print-on-Demand charts: up-to-date paper charts with current Notice to Mariners corrections
- Raster Navigational Charts® (NOAA RNC®): bitmap electronic images of paper charts
- Electronic Navigational Charts® (NOAA ENC®): vector charts that conform to international standards

NOAA also produces several nautical publications. For example, the United States Coast Pilot® is a series of nautical books with a variety of important information for navigations to supplement the nautical chart.

### Nautical Charts & Products
- Traditional Paper Charts
- Print-on-Demand Charts (POD)
- Raster Navigational Charts: NOAA RNC®
- Electronic Navigational Charts: NOAA ENC®
- PocketCharts
- PocketChart® (Experimental)
- Chart Updates (NM and NM Corrections)

### Nautical Charting Publications
- United States Coast Pilot®
- Symbols and Abbreviations (U.S. Chart No. 1)
- Chart Catalog
- Dates of Latest Editions (DOLE)
- Upcoming New Editions (SON)
- Distances Between U.S. Ports

### Nautical Charting Utilities
- NOAA's On-Line Chart Viewer

### Historical Products
- Historical Maps and Charts
- Historical Coast Pilots

### Learn About Charting Products
- Obtain Charting Products
- How a Chart is Updated
- Differences Between Maps & Charts
- Learn About Nautical Charts
- DSSP & Your Chart
- Differences Between NM and LNM
- Differences Between RNCs and ENCs
- Differences Between NOAA ENC® and DNC®
- Differences Between ENC and ENC2Direct to GIS

### Data Portals
- Tides and Currents (General)
- navaCOAST: Real-Time Coastal Data Map Portal
- Physical Oceanographic Real-Time System (PORTS®)
- Nautical Charting Links

### Resources
- Coast Survey Partners
- Chart carriage requirements
- Report a Charting Discrepancy
- Chart Inquiries (questions/comments)
- Cartographic Automation
- Nautical Chart Calendars
Show polar view at work
Traditional Beach Profiles

Offshore Survey

High Tide

Low Tide

Land Survey

Bench Mark

Boat survey
Baseline
Surveyor or GPS

Beach survey
Baseline
Surveyor or GPS
GPS-equipped ATV, Jet ski

USGS (List at Duck, NC)
Tools

Theodolites
GPS
Lasar ranging
Beach Survey

Profiles

Baseline

Volume of Survey $n$

$V_n = \Delta y \left( \frac{A_1}{2} + A_2 + A_3 + \ldots + A_{n-1} + \frac{A_n}{2} \right)$

Volumetric Change (n to (n-1))

$\Delta V_n = V_n - V_{(n-1)}$
Depth of Closure

Surveys should be unchanged at depth of closure
Variations due to:
  Survey error (tide, calibration)
  Bottom changes

Measurements:
  Survey rods (diver inspected)
  Rods with disks
  Dyed sand
Multibeam Sonar
Aerial Photography

Historical Data Base
Google Earth

Need:  good photos
      optical correction
      known landmarks
      obvious waterlines
LIDAR

Synoptic, wide areas
(needs clear water for SHOALS)
(Scanning Hydrographic Operational Airborne Lidar Survey)

Shoreline Change Data

2000 1990 1950

Ocean

What can you tell from this?

Can calculate recession rates
Analysis of Surveys

Beach Change Analysis
Calculate Volumetric Change between surveys
Equilibrium Profile

\[ d_c = h^* \]

\[ A = R (B + h^*) \]

Example: \( h^* = 20', B = 10', R = 1' \)

\[ A = 30 \text{ ft}^2/\text{ft} = 1.1 \text{ yd}^3/\text{ft of beach} \]

1 ft recession \( \rightarrow \) 1 yd\(^3\) erosion
Analysis of Profiles

a) Change of daily nearshore energy flux

b) Offshore changes in wave energy profile

c) Changes of shoreline beach slope
One Year of Profile Change at FRF

http://www.usna.edu/Users/oceano/pguth/tp/teaching_philosophy_web/duck_profiles.htm
Consider a given profile and many surveys (K surveys)

Survey: Depths

1: \( h_1, h_2, h_3, \ldots, h_{(N-1)_k}, h_I \) depths in profile \( k \)

2: \( h_{1_1}, h_{2_1}, h_{3_1}, \ldots, h_{(N-1)_1}, h_{I_1} \)

\[ k_{i_k} = \sum_{n=1}^{N} C_{n_k} e_{n_i} \]
where \( C_{n_k} \) are weights for \( n^{th} \) eigenfunction and \( k^{th} \) profile
\( e_{n_i} \) is the \( n^{th} \) eigenfunction at location \( i \)

\[ e_{1_i} = e_{1_1}, e_{1_2}, e_{1_3}, \ldots, e_{1_{I-1}}, e_{1_I} \]

We are interested in the most important of the \( e_{n_i} \)
as they are not equally important
Empirical Orthogonal Eigenfunctions

\[ e_{n_1} \]

Winant et al. (1975)
EOF

Force orthogonality of the $e_{ni}$

$$
\sum_{i=1}^{I} e_{ni} e_{mi} = \delta_{nm} \text{ where } \delta_{nm} = \begin{cases} 
1 & \text{if } m = n \\
0 & \text{otherwise}
\end{cases}
$$

To find $C_{nk}$, minimize mean square error in fit

$$
E = \sum_{i=1}^{I} \epsilon_{ik}^2 \text{ where } \epsilon_{ik} = h_{ik} - \sum_{n=1}^{N} C_{nk} e_{ni}
$$

$$
\frac{\partial E}{\partial C_{mk}} = 2 \sum_{i=1}^{I} \epsilon_{ik} \frac{\partial \epsilon_{ik}}{\partial C_{mk}} = 0
$$

$$
2 \sum_{i=1}^{I} \left( h_{ik} - \sum_{n=1}^{N} C_{nk} e_{ni} \right) e_{mi} = 0 \\
\sum_{i=1}^{I} h_{ik} e_{mi} - \sum_{n=1}^{N} C_{nk} \sum_{i=1}^{I} e_{ni} e_{mi} = 0
$$

$$
C_{mk} = \sum_{i=1}^{I} h_{ik} e_{mi}
$$

Much like Fourier series
Now, find eigenfunctions by defining mean squared variance of the profile

\[ \sigma^2 = \frac{1}{IK} \sum_{k=1}^{K} \sum_{i=1}^{I} l_{ik}^2 \]

sum over surveys (k) and points in profile (i)

\[ \sigma^2 = \frac{1}{IK} \sum_{k=1}^{K} \sum_{i=1}^{I} \left( \sum_{n=1}^{N} C_{nk} e_{ni} \right) \left( \sum_{m=1}^{N} C_{nk} e_{mi} \right) = \frac{1}{IK} \sum_{k=1}^{K} \sum_{n=1}^{N} C_{nk}^2 \]

Parseval’s Theorem

For an eigenfunction, maximize its contribution to \( \sigma^2 \) while constraining the magnitude of the eigenfunction to unity (in addition to the orthogonality constraint)

\[
\frac{\partial}{\partial e_{nm}} \left\{ \frac{1}{IK} \sum_{k=1}^{K} \sum_{n=1}^{N} C_{nk}^2 - \lambda \left( \sum_{i=1}^{I} e_{ni}^2 - 1 \right) \right\} = 0
\]
Find eigenfunction

but \[ \frac{\partial C_{m k}}{\partial e_{n_m}} = \frac{\partial \left( \sum_{i=1}^{I} h_{i_k} e_{n_i} \right)}{\partial e_{n_m}} = h_{m_k} \]

\[ \frac{2}{IK} \sum_{k=1}^{K} \left( \sum_{i=1}^{I} h_{i_k} e_{n_i} \right) h_{m_k} - 2\lambda e_{n_m} = 0 \]

\[ \sum_{i=1}^{I} \left( \frac{1}{IK} \sum_{k=1}^{K} h_{i_k} h_{m_k} \right) e_{n_i} = \lambda e_{n_m} \]

Eigenvalue problem for \( e_{n_m} \)

or \[ \sum_{i=1}^{I} a_{i m} e_{n_i} = \lambda e_{n_m} \text{ for } m = 1, 2, \ldots, I \]

\[ a_{i m} = \frac{1}{IK} \sum_{k=1}^{K} h_{i_k} h_{m_k} \]
Eigenfunctions

Profiles

Torey Pines Beach: Indian Canyon Range

Distance in Meters

0 200 400

5

Depth/Elevation

-5

-10

Planforms

Dick & Dalrymple (1984)

Complex EOF

Complex Principal Component Analysis

References:

http://www.hooimeijer-it.com/tudelft/Resources/EOFrefs.htm
Sand Budget

Examine sediment fluxes into and out of a rectangular box of depth $h$

Sediment entering box in time $dt$ is $(q_x \, dy \, dt + q_y \, dx \, dt)$

Sediment leaving the box is

\[
(q_x + \frac{\partial q_x}{\partial x} \, dx \, dt + (q_y + \frac{\partial q_y}{\partial y} \, dy \, dt) \, dx \, dt)
\]

Sediment lost from the box is:

\[
[h(t + dt) \, dx \, dy - h(t) \, dx \, dy]
\]

Taylor Series: $h(t + dt) = h(t) + \frac{\partial h}{\partial t} \, dt + \ldots$

Equating volumes:

\[
\frac{\partial h}{\partial t} = \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y}
\]

Conservation of Sand

Really the volume lost; probably need to derive Taylor series
Sand Budget

\[ \frac{\partial h}{\partial t} = \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} - s \]

s is a source term (volume per unit area per unit time)

Equation used for modeling

Integrate over a longshore direction \((y_1 \text{ to } y_2)\), an offshore direction \((x_1 \text{ to } x_2)\) and time \((t_1 \text{ to } t_2)\)

\[ V_{y1} = \int_{t_1}^{t_2} \int_{x_1}^{x_2} q_y(x, y_1, t) \, dx \, dt \]
Sand Budget

Accumulated sediment in volume

\[ \Delta V_s = V_{x1} - V_{x2} + V_{y1} - V_{y2} + S \]

- \( V_{x1} \) = the volume of sand carried into the study area alongshore,
- \( V_{x2} \) = alongshore volume of sand leaving the study area alongshore,
- \( V_{y1} \) = volume of sand transported from onshore,
- \( V_{y2} \) = volume of sand going offshore out of the area,
- \( S \) = volume added artificially within the study area
Sand Budget Analysis
Indian River Inlet, Delaware
Even-Odd Analysis

\[ \Delta V_e(x) = \Delta V_e(x) + \Delta V_o(x) \]

For negative x, we have

\[
\begin{align*}
\Delta V_e(-x) &= \Delta V_e(-x) + \Delta V_o(-x) \\
&= \Delta V_e(x) - \Delta V_o(x)
\end{align*}
\]

Use these two equations to solve for even and odd functions

\[
\begin{align*}
\Delta V_e(x) &= \frac{1}{2}(\Delta V_e(x) + \Delta V_o(-x)) \\
\Delta V_o(x) &= \frac{1}{2}(\Delta V_e(x) - \Delta V_o(-x))
\end{align*}
\]

Example

Do example