Bathymetric Techniques

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Introduction

Definition

Bathymetry is the measurement of water depth: height from water bed to water surface. (Sounding)

- Measures the vertical distance from the ocean surface to mountains, valleys, plains, and other sea floor features

- 70.8% of Earth is covered by oceans

Importance of Bathymetry

- Importance:

- Navigation Safety: Nautical charts
- Water volume computation
- Pollution control
- Mineral & Fish industries
- Under water engineering construction
- Harbor & Docks construction & maintenance

History of Sounding

- SOUNDING: WATER DEPTH MEASUREMENT
  Poseidonus did the first sounding in 85 B.C.

  Line with heavy weight was used, called sounding line
  Sounding lines were used for 2000 years

- UNIT OF MEASURE IS A FATHOM
  1 fathom =1.8 meters (6 feet)
  1- Sounding Pole
  2- Sounding Line

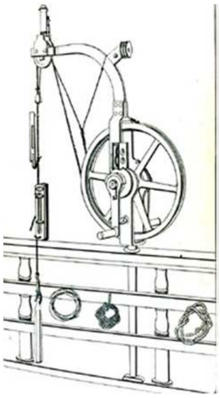
Historical Sounding

- Sounding Pole:

sounding Lead

History of sounding

Sounding Machines



Charles Wilkes (NOAA)

Lord Kelvin

Echo Sounding

Echo Sounding Instrumnt:

Echo sounder or fathometer

Reflection of sound signals

German ship Meteor identified mid-Atlantic ridge in 1925 using echo-sounder.

Disadvantages:

Point by point sounding has disadvantages:

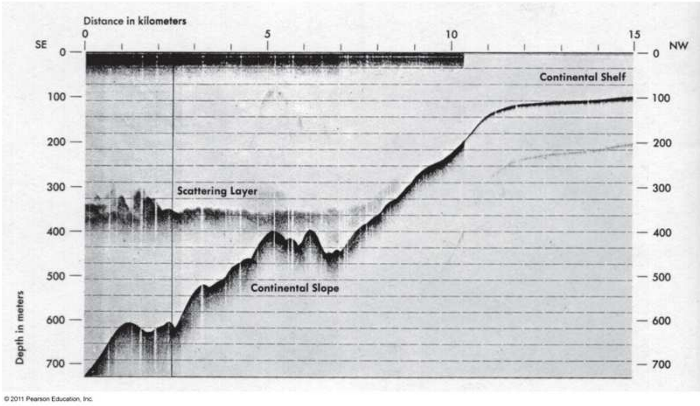
-Lacks detail

-May provide inaccurate view of sea floor

-Time and cost consuming for large sea or ocean coverage

Echo Sounding

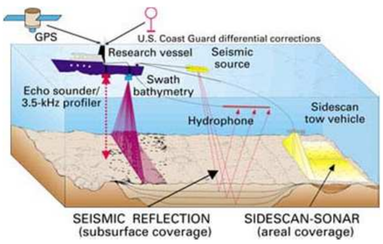
Recorded depth from echo-sounder



Echo Sounding

Precision Depth Recorder (PDR)

- 1950s
- Focused high frequency sound beam
- First reliable sea floor maps produced
- Helped confirm sea floor spreading



Modern Echo Sounding

Modern Acoustic Instruments

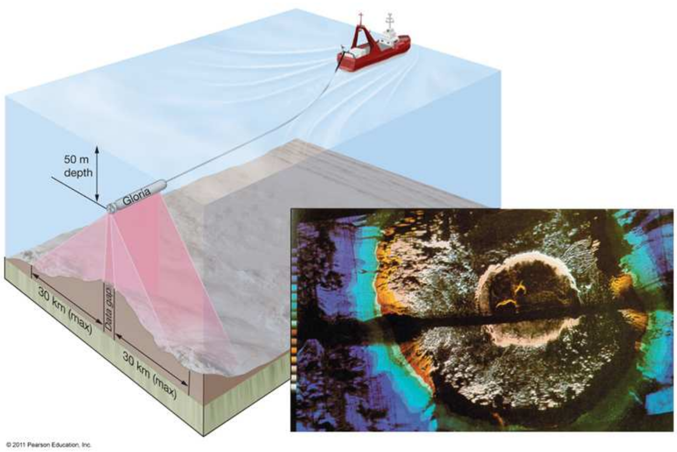
Side scan sonar

- GLORIA (Geological Long-range Inclined Acoustical instrument)
- Sea MARC (Sea Mapping and Remote Characterization)

This can be towed behind ship to provide very detailed bathymetric strip map

Multi-beam echo sounder

Side Scan Sonar



Echo Sounding

Disadvantages:

- measurements are the time and cost associated with making measurements from a ship in deep waters or a small vessel in shallow waters.

- In order to build up coherent images at high resolution many survey lines with overlapping tracks must be run.

- Because the swath width decreases in shallow water, many more ship or glider tracks are required in coastal estuaries and bays with shallower water.

Echo Sounding Disadvantage

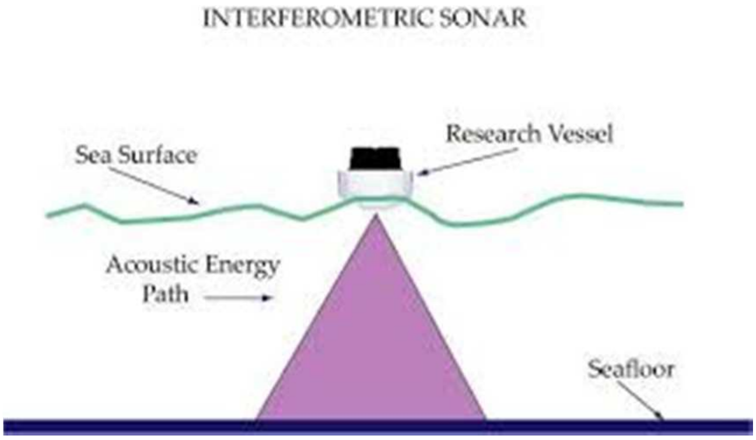
- Detailed surveys in coastal regimes require considerable time and effort to cover relatively small portions of the sea bed.

- ship time is costly even in deep water and because of increasing time and effort to operate in shallow waters, acoustic systems are not ideal for such tasks as monitoring bathymetric changes and shoreline.

- However, acoustic methods can be used throughout all oceanic depths from shallow estuaries to the deepest trenches.

Inter-ferometric Sonar

Inter-ferometric Sonar



Multi Beam Sonar

Increased:

- **Bottom Coverage**
- **Productivity**
- **Resolution**
- **Confidence**

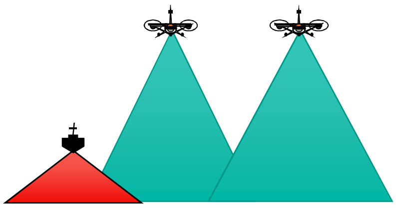
Vertical Beam Echo-sounding (VBES)

Used from 1939 to the present

Better coverage than lead-lines

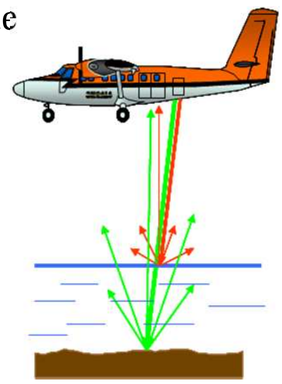
Airborne LIDAR

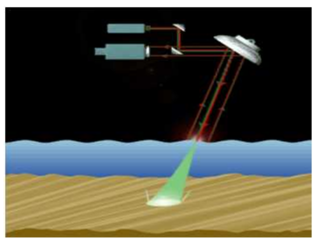
- **Airborne laser scanning technology** to survey both land and coastal waters in a single approach, employing a technique known as Airborne LIDAR Bathymetry (ALB) or Airborne LIDAR Hydrography (ALH) which uses state-of-the-art LIDAR Technology to measure sea bed depths and topographic features rapidly and accurately.



SHOALS

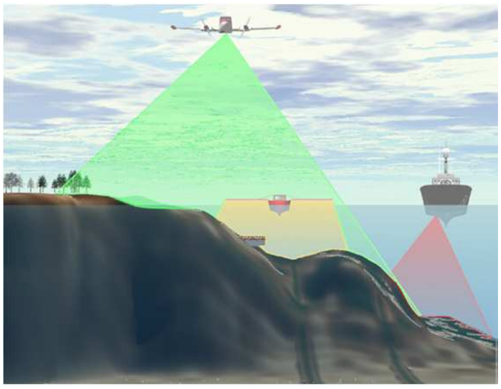
Green pulses (532 nm) reflected
from bottom
N-IR (1064 nm) laser pulses
reflected from water surface





SHOALS

Simultaneous costal zone survey, both land and water under one approach



Aerial Photography

- Photo Bathymetry was used to measure water depth for shallow water with depth not more than 30m
- Refraction of light passing from water to air layers should be corrected first.
- Both single aerial photo and overlapping photos can be used.
- Covered area is limited by camera focal length
- Depth limitation is the most serious disadvantage.

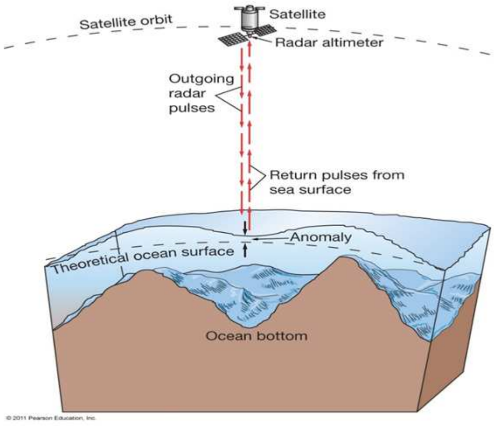
Satellite Radar Altimetry

- The surface of the ocean bulges outward and inward representing the topography of the ocean floor. The bumps, too small to be seen, can be measured accurately by a radar altimeter aboard a satellite.

- the Geosat and ERS-1 altimeter data are comparable in value to the radar altimeter data collected by the Magellan spacecraft during its systematic mapping of Venus. (D.T. Sandwell & W.H.F. Smith)

Satellite Radar Altimetry

satellite measurements of sea floor features is based on gravitational bulges in sea surface caused by underwater topography change



Radar Altimeter

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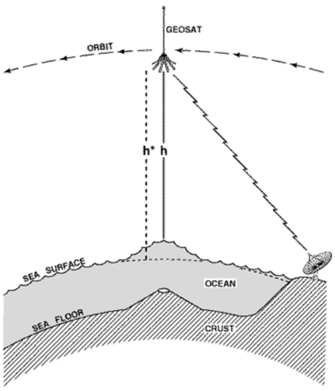
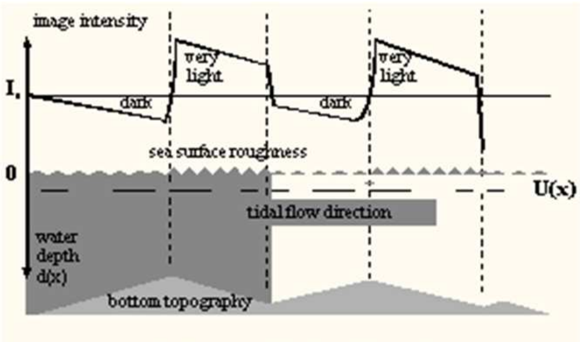
Applications of Satellite Altimetry

- Navigation
- Prediction of Seafloor Depth
- Planning Shipboard Surveys
- Plate Tectonics
- Undersea Volcanoes
- Petroleum Exploration
- Lithospheric Structure



Radar Underwater topography

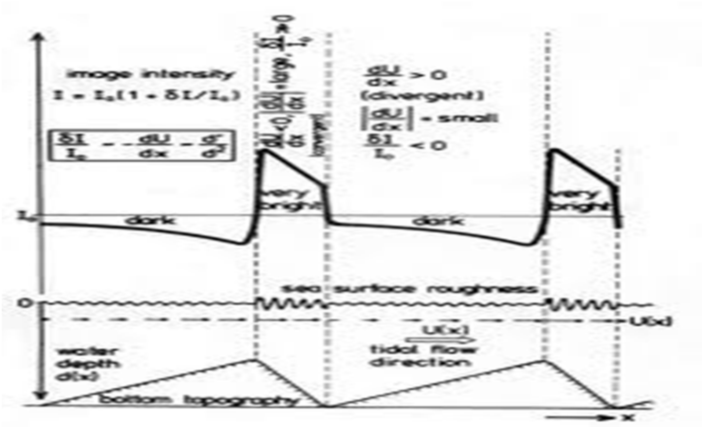
- Radar signal reflected from water surface, surface smoothness is represented as DN on sensor (Hesselemans, et al, 2014). Water surface roughness is affected by under water topography



Bathymetry by imaging radar

Underwater Topo

- RADAR signal power is a function of water surface roughness



Satellite Optical Bathymetry

- Optical light bathymetry Theory:
- The simple water reflection model was first given by Lyzenga 1978. According to this model the radiance in a single band can be written as
- $L_i = L_{si} + K_i \; R_B \; \exp(-K_i f Z_i)$
- Rearranging the above equation for a water depth determination algorithm gives
- $Z_i = [1n \; C_{1i} – 1n \; (L_i – C2_i) \;] \,/\, C_{3i}$

Optical Light Bathymetry

- Assuming that the ratio of bottom reflectance between two spectral bands is constant for all bottom types within a given scene, Lyzenga (1978; 1981; 1985) derived a bathymetric inversion model for two (and/or multiple) spectral bands as follows:
- **$z = a_0 + \text{SUM } i\text{=1 to N } [a_i \ln[L(\lambda_i) - L_\infty(\lambda_i)]]$**
- where a_i (i = 0,1, . . . , N) are the constant coefficients, N is the number of spectral bands,
- $L(\lambda_i)$ is the remote sensing radiance after atmospheric and sun glint corrections for spectral band λ_i , and $L_\infty(\lambda_i)$ is the deep water radiance for spectral band λ_i .

Optical Satellite Bathymetry Accuracy

- Hsu, et al (2008) on their case study of Molokai illustrated that depth estimates can be derived from high resolution IKONOS multi-spectral imagery with vertical accuracy of about 2 m (RMSE) in water depths down to 20 m.
- Although this level of vertical accuracy (2m) does not meet International Hydrographic Office (IHO) standards for safe navigation, these bathymetric data are highly valuable for many other purposes.

Satellite Optical Bathymetry

- Bathymetric information retrieval from optical satellite multispectral imagery enjoys the advantages of:
- large surface coverage.
- low-cost. As demonstrated (by many researchers)
- Subtle and detailed morphological features can be detected and quantified using the image-derived bathymetric data.
- Given that expansive areas of coastal bathymetry still need to be surveyed, bathymetric data derived from optical multispectral remote sensing imagery represents a valuable alternative to costly ship-borne echo sounding and airborne LiDAR surveys.
- This is particularly true for remote areas and developing countries.

Satellite Optical Bathymetry

- All light and imaging techniques are dependent on the water clarity.
- Thus, all light and imaging techniques are susceptible to error with murky water.
- The disturbing restriction is the limited water depth that can be measured. This is due to the fact that optical light cannot penetrate even pure water for a depth more than 40m.

Conclusions

- Knowledge of ocean bathymetry has progressed rapidly in the last century due to the advancement of techniques using acoustics, optics, and radar.
- The ocean has been mapped at a variety of spatial resolutions but considerable work has yet to be done to accurately map the vast underwater landscape.
- More acoustic soundings are required to validate gravimetric bathymetry in remote regions of the world.
- Marine radar systems mounted on coastal stations have been used to infer nearshore bathymetry.
- The technique was recently expanded for radar measurements collected on moving vessel proving to be quite accurate down to 40-50 m water depth with a horizontal resolution of 50-100 m pixels.

Recommendation

- For further research:
- It is recommended to continue research on using Radar altimetry

for finding out water depths with higher accuracy for deeper waterbed.

- Effective mathematical models relating underwater topography and sea surface roughness is expected o be the key for the solution.

Thank You

All

END