Measuring the Qualities of the Ocean

John Schulz
2/21/2007
Definitions

- OCEANOGRAPHY – the study of the ocean with emphasis on its character as an environment. The goal is to get a description sufficiently quantitative to be used for predicting the future.

- HYDROGRAPHY – the preparation of nautical charts, including charts of ocean depth, ocean currents, internal density and ocean fields.
General Information

• The US Navy is generally interested in Hydrographic studies.
• Data is gathered by special Hydrographic ships and forwarded to the Hydrographic Office in the USA.
• Hydrographic studies have been conducted since the 1600’s.
• The specific Hydrographic project used as an example for this presentation was the study of the waters of the Mediterranean Sea between the coast of Turkey and the Island of Crete in 1958 as experienced by the author.
US Navy Hydrographic Ships – 1958

- Converted WWII Troop Transports
  - USS Tanner
  - USS Maury

- Converted WWII Minesweepers
  - USS Pursuit
  - USS Sheldrake
  - USS Rehobeth
US Navy Hydrographic Ships – 2000

- Approved for Public Release
- UNCLASSIFIED
- 2000

- Navy Military Survey Ships
  - USNS John
  - McDonnell
  - T-AGS 51
  - USNS Sumner
  - T-AGS 61
  - USNS Henson
  - T-AGS 63
  - USNS Heezen
  - T-AGS 64
  - USNS Pathfinder
  - T-AGS 60
  - USNS Bowditch
  - T-AGS 62
  - USNS Mary Sears
  - T-AGS 65
Qualities To Be Measured

- Depth and Topography
- Salinity at Various Depths
- Temperature Gradients
- Underwater Currents
Baseline Measurement - Location

- Very accurate location coordinates needed for all data collected.
- Easy in 2007 – Use GPS
- Not easy in 1958
  - No GPS
  - No Loran or Shoran
  - Star Sights – not accurate +/- 2 to 3 miles
  - What Could We Do?
Location — What Did We Do?

• Use Triangulation
  – Find 3 shore based locations
  – Set up shore camps for 24/7 radio signals
  – Man the camps-3 men
  – Only duty is to keep radio transmitting 24/7
  – Ship sends food once a week
Depth And Topography—Why Do We Need This Information

- Used by Submarines and other ships to avoid underwater obstacles
- Used by Submarines to find underwater "hiding places"
- Used by Submarines to avoid exceeding maximum depth when lying on bottom
Depth & Topography – Equipment Used in 1958

• FATHOMETER (also known as Acoustic Echo Sounder)
• Accuracy is +/- 1%
Depth & Topography — Method Used in 1958

- Select a Zone to be measured and plotted
- Lay out parallel grid lines and determine interval of depth measurements while steaming on the lines
- Using triangulation guide signals, ship steams along the lines gathering depth readings.
- Ship steams back and forth until zone is complete
- Data sent to Washington DC
Depth & Topography — Equipment Used in 2007

• Fathometer- single beam (as before)
• Multibeam Fathometer – circular path
• Satellite Altimetry (used to fill in the gaps between the sound lines)
  – A seamount produces a slight bulge on the surface of the sea (approx bulge from a 2km high seamount is 10 meters). Oceanic trenches produce a depression on the surface
Depth & Topography—Method
Used in 2007

• Select a Zone to be measured and plotted
• Lay out parallel grid lines and determine interval of depth measurements while steaming on the lines
• Using GPS signals, ship steams along the lines gathering depth readings.
• Ship steams back and forth until zone is complete
• Data sent to Washington DC
Salinity & Temperature At Various Depths — Why Do We Need This Information?

• We need to know the Salinity and sea temperature at various, known depths of the ocean.
  – This data produces very general maps of the average arrangement of water masses and average patterns of circulation.
Salinity & Temperature At Various Depths — Why Do We Need This Information?

• When submarines use their forward looking fathometers, they need to make corrections due to salinity and temperature.
  
  – The velocity gradient of a sound pulse in water is a function of the sum of salinity and temperature gradients. Sound pulses get diffracted because of variation in density as a result of non-uniformity of salinity and temperature.
Salinity & Temperature At Various Depths — Why Do We Need This Information?

Diagram from Patent 2,967,662 - 1961 - Submarine Depth Computer
Salinity & Temperature At Various Depths — Why Do We Need This Information?

• Provides for detection of Thermoclines
  – A thermocline is a thin boundary layer of water that separates two layers of water with significantly different temperatures
  – used by submarines to foil sonar detection
Salinity & Temperature At Various Depths — Equipment Used in 1958

• Nansen Bottles
  – cylindrical containers that sample sea temperature and salinity.
  - The bottles are attached at specific intervals to a cable that will reach the bottom.
  - The cable is lowered to the bottom and the bottle covers are tripped and the sample is captured.

(From Dietrich et al. 1980)
Salinity & Temperature At Various Depths — Method Used in 1958

- Nansen Bottles
  - Photo taken aboard the USS Pursuit (AGS17) while performing a Nansen Bottle drop of the coast of southern Turkey in July 1958
Salinity & Temperature At Various Depths – Equipment Used in 2007

- Nansen Bottles were replaced in the early 1960’s, whereby the mechanical instruments in the bottles were replaced by an electronic instrument called a CTD that measured conductivity (to measure salinity), temperature and depth.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
<th>Best Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>42°C</td>
<td>±0.001°C</td>
</tr>
<tr>
<td>Salinity</td>
<td>1</td>
<td>±0.02 by titration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±0.005 by conductivity</td>
</tr>
<tr>
<td>Pressure</td>
<td>10,000 dbar</td>
<td>±0.65 dbar</td>
</tr>
<tr>
<td>Density</td>
<td>2 kg/m³</td>
<td>±0.005 kg/m³</td>
</tr>
<tr>
<td>Equation of State</td>
<td></td>
<td>±0.005 kg/m³</td>
</tr>
</tbody>
</table>
Salinity & Temperature At Various Depths — Equipment Used in 2007

- This is a photo taken on a modern Hydrographic ship using the CTD instrument that will measure the data electronically.
Underwater Currents Why Do We Need This Information?

- Location, direction and velocity of underwater currents information is extremely useful to submariners.
- This information is used by surface ships in deciding the best route.
- Scientists can determine how nutrients, and other biological and chemical constituents are transported by the ocean.
Underwater Currents — Equipment used in 1958

• A “homemade” rig was used.
  – A weighted line was floated vertically using a 5 gallon gas can as a float.
  – A WWII aviation parachute was attached to the line at the depth the underwater current was detected.
  – The ship then followed the float while recording the speed (of the ship) and its location (triangulation).
Underwater Currents — Equipment used in 1958

- float
- parachute
- ship
- weight
Underwater Currents — Equipment used in 2007

• “The Drifter”
  – Uses same technique as in 1958, but is completely automated.
  – Has four major parts; waterproof tubular body, sails, spherical floats and electronic data collection/transmitter package.
  – Once in the water, the transmitter sends signal to Earth polar orbiting satellite which calculates position and relays to receiver.
Underwater Currents — Equipment used in 2007

- “The Drifter”

Four major components make up a drifter. They include a waterproof tubular body, sails, spherical floats, and a data collection/transmitter package. Click image for larger view.
Underwater Currents — Equipment used in 2007

• The Acoustic Doppler Current Profiler (ADCP)
  – Measures speed and direction of ocean currents using the principle of “Doppler Shift”.
  – The ACDP has 4 acoustic transducers that emit and receive pulses from 4 different directions allowing trigonometric relations to determine its location.
  – The ADCP is mounted on the bottom of the ship and sends signals to the ocean bottom allowing it to measure currents at different depths simultaneously.
Underwater Currents – Equipment used in 2007

- The Acoustic Doppler Current Profiler (ADCP)

ADCP sensor head: Typical 4 beam ADCP sensor head. The red circles denote the 4 transducer faces. Click image for larger view.
The Modern Hydrographic Ship

TAGS-60 Class

Data Processing
Vertical Reference
Satellite Communications
Acoustic Release System
Satellite Navigation (GPS)
Meteorology Sensors

Regulated Power System

Measurement Buoy
Side-Scan Sonar
Seismic Profiling
CTD Profiler
Expandable Sensors
Magnetic Intensity

Length: 329 ft (100 m)
Beam: 58 ft (18 m)
Draft: 19 ft (5.8 m)
Endurance: 12,000 nmi @ 12 knots
Displacement: 5000 tons (4535 metric tons)

Multibeam Contour Mapping System
Deep and Shallow
Subbottom Profiler
Wide-Beam Shallow Water System
Wide-Beam Deep Water System

Approved for Public Release  Naval Oceanographic Office  2006
AND THAT’S JUST THE TIP OF THE ICEBERG