Week 1 Oceanography Lab Exercise Notes
Introduction to Oceanographic Maps

I. Introduction
  A. Map- a 2-d, scaled representation of the earth's surface,
    1. Model of Earth's Surface
    2. Basic functions: to represent horizontal distance, direction, size, and shape, as well as distributions of phenomena.

  B. "No map is perfectly accurate" - inaccuracy of a map is ubiquitous because it projects a curved surface on a flat piece of paper.

  C. Map Components
    1. Title / Type of Map
      a. Road Map, Geologic Map, Topographic Map, Hydrologic Map, etc.
      b. Location of Map Coverage
    2. Compilation Date (When was the map made?)
    3. Legend / Explanation of Map Symbols
    4. North Arrow / Geographic Frame of Reference
      a. Georeference
        (1) e.g. Longitude and Latitude
      b. Geographic Directions: North, South, East, West

    5. Map Scale
      a. Mathematical Relationship Between Map Distance of Model and Actual Ground Distance

II. Methods of Earth Representation
  A. Globes or spherical models:
    1. provides the most accurate portrayal of the sphericity of the earth, but is limited in its use. (size must be at small scale, and not functional for transport, plus does not provide regional detail).

  B. Digital Computer Models
    1. Geographic Information Systems
    2. Digital Maps

  C. 2-D Paper Maps (Traditional)

  D. Map Projections
    1. Problem: projecting a 3-D sphere on a 2-D surface
      a. All Maps Have Inherent Error in Representation
      b. The Larger the Area of Coverage: the greater the spatial error

2. Modeling Approaches
   a. Accurate Scaled Areas vs. Accurate Geometric Shapes

   b. Equivalence vs. Conformality
      (1) Equivalence: Map Projection Preserves Scaled Relationships Between Areas
         (a) e.g. Continental Land Areas
         (b) Created at the Expense of Shape Accuracy

      (2) Conformality: Map Projection Preserves Scaled Relationships Between Map Shapes
         (a) Created at the Expense of Areal Accuracy

3. Example Map Projections (100's of ways to project a 3-D sphere onto a 2-D surface)
   a. Cylindrical Projection
   b. Conical Projection

III. Georeferencing System - (Grid Location Coordinates)
   A. Grid Location Network
      1. Standard Grid
         a. East-West Lines (Horizontal)
         b. North-South Line (Vertical)
      2. Frame of Reference
         a. Rotational axis- a diameter line that passes through the center of the Earth, about which the Earth rotates or spins about.
            (1) North Pole rotational axis- point of intersection of rotational axis at the upward portion or top side of the Earth

            (2) South Pole rotational axis- point of intersection of rotational axis at the downward portion or bottom side of the Earth

         b. Plane of the equator - an imaginary plane that passes through the Earth halfway between the poles and perpendicular to the axis of rotation

            (1) Equator- imaginary line of intersection formed between the surface of the Earth and the plane of the equator.
         c. Great Circles - any line formed by the intersection of any imaginary plane through the center of the Earth (e.g. the

equator is a great circle, so are lines of longitude)

d. Small Circles - any line formed by the intersection of any imaginary plane not passing through the center of the Earth (e.g. Tropic of Capricorn or Cancer are small circles, or the Arctic Circle)

BASIC RULE OF DISTANCE BETWEEN TWO POINTS ON A SPHERE: Given any two points on a sphere, only one great circle can be constructed to pass through those points and through the center of the Earth. The arc between the two points formed by such an intersection is the shortest distance between those two points (a.k.a. "great circle routes")

e. Angular Measurement (based on circle)
- (1) Full Circle = 360 degrees
  - (a) 1 degree = 1/360 th of circle

- (2) Subdivisions of Degree
  - (a) 1 degree = 60 minutes
  - (b) 1 minute = 60 seconds
  - (c) 1 degree = 60 min x 60 sec/min = 3600 sec

- (3) Famous Angular Measurements
  - (a) Right Angle = 90 degrees
  - (b) Line = 180 degrees
  - (c) Circle = 360 degrees

B. Longitude and Latitude

a. Latitude- angular distance measured north and south of the equator.
- (1) Any point on surface of Earth, can be identified by an angle drawn from that point through the center of the Earth to the great circle of the Equator
- (2) Result 0-90^{o} N and 0-90^{o} S of the equator,
- (3) Famous Latitudes
  - (a) Equator = 0 lat.
  - (b) North Pole = 90 N lat.
  - (c) South Pole = 90 S lat

- (4) Lines of Latitude = "parallels" = East-West Lines
  - (a) a line connecting points of the same latitude on the globe
  - (b) all will be parallel to line of equator (and will be small circles except the equator),
  - (c) aligned in true east-west directions,

(d) measures the north-south position of a point.

(e) Other Famous Parallels

i) Tropic of Cancer: 23 1/2^{o}N,

ii) Tropic of Capricorn: 23 1/2^{o}S,

iii) Arctic Circle: 66 1/2N,

iv) Antarctic Circle: 66 1/2S

1. Longitude- Angular distance measured east-west on the Earth's surface

a. Meridians- longitude represented by imaginary lines, passing from north to south pole, oriented at right angles to lines of latitude.

(1) great semicircles, aligned in a north-south direction, measuring the east-west position of a point

b. Prime Meridian- the standard reference meridian that passes from the north pole to the south pole, via Greenwich, England

(1) Angles of longitude measured from 0-180^{o} east of the prime meridian,

(2) 0-180^{o} west of the prime meridian

C. Other Grid Reference Schemes

1. Engineering Approach: "Eastings" and "Northings"

a. Eastings: feet east / west of a north-south reference line

b. Northings: feet north / south of an east-west reference line

c. Frame of Reference: Arbitrary N-S and E-W reference lines established

2. UTM = Universal Trans-Mercator Georeference

a. Easting / Northings in Meters from Established Zero Grid Lines

3. State Plane

a. Easting / Northings in Feet from State-by-State Zero Grid Lines

IV. TOPOGRAPHIC / BATHYMETRIC MAPS

A. Definition- 2-d representation of a 3-d land surface, topographic map illustrates relief of a land surface.

1. includes cultural features such as water bodies, vegetation, roads, buildings, political boundaries, and location names.

B. Topographic Quadrangles- topo maps published by the U.S. Geological Survey in the form of topographic quadrangle maps.

1. Quadrangle- a section of the earth's surface defined by lines of

latitude and longitude.

a. common sizes of topographic maps: 7.5 minute and 15 minute series:
   (1) 7.5 min = an area of earth, 7.5 min longitude x 7.5 min latitude,
   (2) 15 min map = 15 min long x 15 min lat.

b. each 15 minute quadrangle can be divided into 4 7.5 minute maps

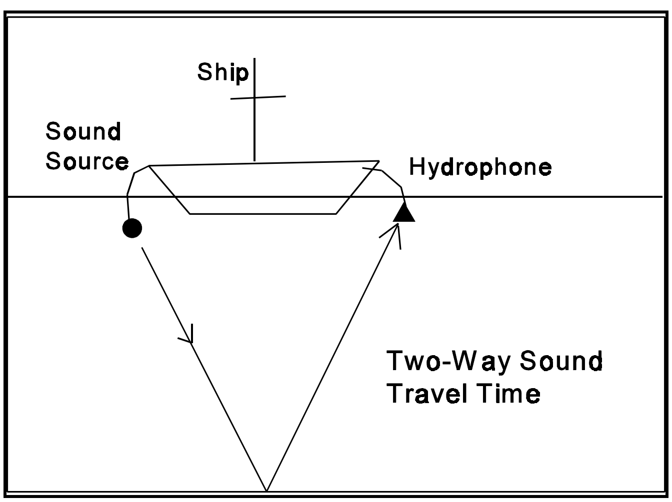
C. Bathymetric Maps

1. Depth measurement and topography of seafloor
2. soundings = depth measurements
   a. echo sounder - uses sound waves and the speed of sound in water to determine the depth to the ocean floor from sea surface
      (1) sound emission source
      (2) hydrophone = sound receiver

   b. velocity of sound in water = 1450 m/sec (4800 ft/sec)

   V = d/t   velocity = distance / time

"two-way travel time" = the time for sound to travel from sea surface to sea bottom, and back to the hydrophone



Example Problem: If the source-hydrophone travel time is 2 sec, what is the depth of the sea floor directly below a ship?

D. Elements of Maps and Ocean Charts

1. North Arrow - points to geographic/rotational north pole of axis.
    a. Geographic/True North- true north pole of earth's rotational axis
    b. Magnetic North- the north pole of the earth's magnetic field: most of the time does not coincide with the earth's true north pole. But a compass needle points to Mag. North

        (1) Earth's Magnetic Field- generated by large scale electromagnetic currents derived from the earth's interior as it rotates.

        (2) Magnetic lines flow from north toward the south pole

        (3) Compass needle points toward north magnetic pole

        (4) Magnetic declination: Angle between True North and Magnetic North

            (a) Changes from point to point depending on one's location on the sphere of the earth:
            (b) the magnetic poles are constantly moving with time

    c. True Geographic North- By convention - always oriented parallel to the vertical edge of the map, towards the top of the map

    d. Magnetic Declination - listed at bottom of map, gives angle of deviation between compass north and true north for a given location

2. Scale: useful in translating map dimensions to true land dimensions

    a. Bar or Graphical scale: a "ruler" at base of map that allows direct conversion from map distances to land distances

    b. Fractional Scale: ratio of map distance to land distance,

        (1) dimensionless ratio e.g. 1:24,000 = 1 distance unit on map = 24,000 of same distance units on ground

(inches, feet, centimeters, millimeters, etc)

c. Verbal scale: e.g. 1 inch = 2 miles on ground.

d. Large vs. Small Scales

(1) Large scale maps- one that has a relatively large representative fraction, a smaller portion of the earth is represented by the map, but it shows much more detail.

e.g. 1/100 is a larger fraction than 1/5000

(2) Small scale maps- one that has a relatively smaller representative fraction, representing a larger land area on the map, and it shows much less detail

e.g. 1/5000 is a smaller fraction than 1/100

3. Map Symbols: symbols used to represent cultural and political features.

4. Contour Lines- special features of topographic maps (separating from other planimetric maps) that allows one to interpret the 3-d topographic relief features of the earth.

a. Contour Lines- lines printed on topo maps that connect points of equal elevation

(1) Elevation- is the vertical height of a given point on the earth's surface above/below sea level.

(2) Contour lines are essentially formed by intersection of imaginary horizontal planes (parallel to sea level) with the land surface, essentially forms lines of equal elevation.

b. Isobaths - lines connnecting points of equal depth on the sea floor

c. Index Contour Line: Darkened and Labelled - Every 5th Contour Line

(1) not all contour lines are numbered, would be too cumberson, the index contour is only numbered,

every fifth contour line forms an index contour, generally a heavier/darker line with a no. for the elevation labelled somewhere on the line.

d. Reading elevations of points:

(1) if a point is on a contour line, then can deteremine the elevation of the contour line relative to the index contours, keeping in mind the contour interval.

(2) if a point lies between two contour lines, then its elevation must be estimated.

e. Relief- the difference in elevation between two points on a map

(1) Local Relief- difference in elevation between two adjacent or local features, such as a hill or valley.

(2) Total Relief- difference in elevation between the highest and lowest points on a map.

f. Benchmarks- a permanent marker that has been surveyed in with a known elevation.

(1) Designated as "BM" followed by a number representing the surveyed elevation relative to sea level.

E. Compass Bearings

1. Bearing- the direction from one point to another,

a. Azimuth Method - angular degrees from 0-360, where north is 0^o or 360^o, east is 90^o, south is 180^o, and west is 270^o.

2. Measuring Bearings- To determine the bearing/direction from one point to another do the following:

a. Draw a line from the first point to the second point

b. using a protractor, center the origin of the protractor on the first point, align the bottom edge with the bottom edge of the map, and the 90 degree tic parallel with true north at the top of the map.

c. Read the angle between north at the 90 degree mark of the protractor, and the line between the two points in question.

(1) Give answer in either the quadrant or azimuth notation.

F. Rules For Drawing Contour Lines Given A Set of Elevation Data (or bathymetric data)

1. Every point on a contour line is of the exact same elevation, that is contour lines connect points of equal elevation

2. Contour lines always separate points of higher elevation (uphill) from points of lower elevation (downhill). One must determine which direction on the map is higher and which is lower by checking adjacent elevations

3. Contour lines may close on themselves to define a circular hill or circular depression

4. The elevation between any two adjacent contur lines is the contour interval. Every 5th contour line is darkened and labelled with its elevation (index contour).

5. Contour lines never cross one another, but they may merge together to form a vertical cliff.

6. Contour lines can never split apart

7. Evenly spaced contour lines represent a uniform slope

8. The closer the contour lines are to one another, the steeper the slope. In other words, the steeper the slope, the closer the contour lines

9. A concentric series of contour lines with highest elevations on the interior, represent a hill

10. A concentric series of contour lines with lowest elevations on the interior, represent a closed depression

11. Contour lines form a V pattern when crossing streams. The apex of the V always points upstream (uphill)

V. Constructing a Topographic Cross Section or Profile

A. Cross-section = profile of earth surface or sea floor as projected along a line that transects the topographic or bathymetric map

1. Profile - analogous to a graph with horizontal distance on the x axis and vertical elevation or depth on the y axis.
2. Echograms - profiles of seafloor bathymetry in which echo sounding data is plotted directly onto profile charts

B. Constructing a Topographic Profile

1. choose a profile line that transects contour lines on the map
2. lay a piece of scrap paper along the line
3. mark the ends of the profile line on the paper
4. wherever a contour line intersects the edge of the paper, make a tick mark and write down the elevation or depth value of the line
5. repeat tick marks and notation for all contours that cross the edge of the scrap paper
6. Lay the edge of the tick-mark paper along the x-axis of a profile graph
7. project ticks vertically upward to the appropriate elevation value on the y-axis, make a point mark at each
8. connnect the plotted points on hte graph with a smooth curve, to represent a topographic profile along the map line

C. Vertical Exaggeration of Topographic Profiles

1. Problem: in cases where the map area is of low vertical relief relative to the horizontal scale, it is necessary to vertically exaggerate the y-axis scale to enhance the visualization of the profile dimensions

2. V.E. = vertical scale / horizontal scale

example: the horizontal scale of a profile is 1:250000, while the vertical scale is 1:10000, what is the vertical exaggeration of the profile

V.E. = (1/10000) / (1/250000) = (250000)/(10000) = x 25

3. V.E. = 1x this is a vertical exaggeration in which the elevation scale is exactlye the same as the horizontal scale (i.e. a 1:1 ratio)