

Coastal Navigation Pt. 1

- Introduction to Navigation
- Coordinate Systems
- Nautical Charts
- Aids to Navigation
- Tides

Coastal Navigation Pt. 2

- The Magnetic Compass
- Obtaining a Fix
- Dead Reckoning
- Navigation Rules
- Electronic Instruments

A detailed nautical chart showing depth contours and soundings. The chart features a grid of latitude and longitude lines. Depth contours are labeled with numbers such as 30, 40, 50, 60, 70, 80, 90, 100, and 110. Various navigational symbols and text are scattered across the chart, including "MAGNETIC" and "DECREASE". The text is overlaid on the chart in a large, black, serif font.

What Is Navigation?

Navigation: Determination of one's position, and velocity. (Where are you?)

Guidance: Determination of the desired path to a destination. (Where are you going? How will you get there?)

Collision Avoidance: Getting there safely.

Types of Marine Navigation

- Dead Reckoning

Starting from a known location, track your position based on the speed and direction your vessel travels over measured periods of time.

- Piloting

Navigating by sight in restricted waters using landmarks such as geographic features and other aids to navigation.

- Celestial Navigation

Determining your position based on the positions of the sun, moon, stars, and other celestial objects, usually measured with a sextant.

Types of Marine Navigation

- Radio Navigation

Determining your position based on radio signals (e.g. RDF, LORAN).

- Radar Navigation

Using radar to determine direction and distance to nearby objects.

- Inertial Navigation

Use of accelerometers and gyroscopes to keep an electronic dead reckoning. Not used much on sailboats.

- Satellite Navigation

Use of satellite based electronic systems; primarily GPS.

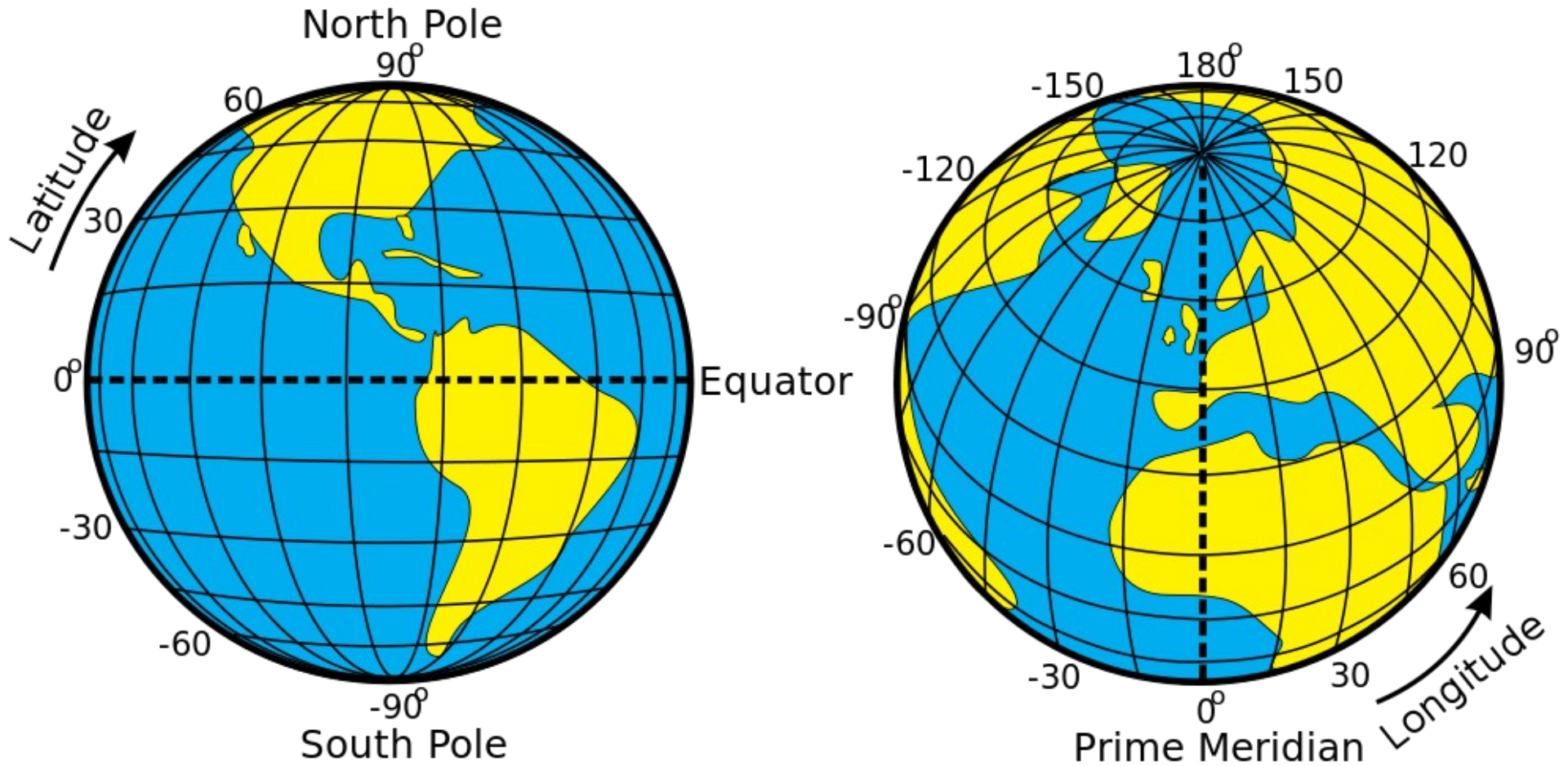
Marine Navigation

The Navigation Rules... expect prudent mariners to avail themselves of *all available means appropriate...* as to make *full appraisal of the situation.*

WARNING

The prudent mariner will not rely solely on any single aid to navigation, particularly on floating aids.

Latitude and Longitude



Parallels of **Latitude**: Position **N**orth or **S**outh of Equator

Meridians of **Longitude**: Position **E**ast or **W**est of Prime Meridian (Greenwich)

Specifying Latitude and Longitude

360 degrees ($^{\circ}$) in a circle
60 minutes ($'$) in 1 degree
60 seconds ($''$) in 1 minute

North & East: positive
South & West: negative

Coordinates of MIT Sailing Pavilion:

$42^{\circ} 21' 30.4''$ N, $71^{\circ} 5' 15.6''$ W
 $42^{\circ} 21.507'$ N, $71^{\circ} 5.260'$ W
 42.35845° N, 71.08776° W
 42.35845 , -71.08776

Latitude should be written first



Specifying Latitude and Longitude

360 degrees (°) in a circle
60 minutes (') in 1 degree
60 seconds (") in 1 minute

North & East: positive
South & West: negative

Coordinates of MIT Sailing Pavilion:

42° 21' 30.4" N, 71° 5' 15.6" W

42° 21.507' N, 71° 5.260' W

42.35845° N, 71.08776° W

42.35845, -71.08776

When specifying coordinates for use in navigation, use degrees and minutes. Be sure to include at least one decimal place for the minutes.



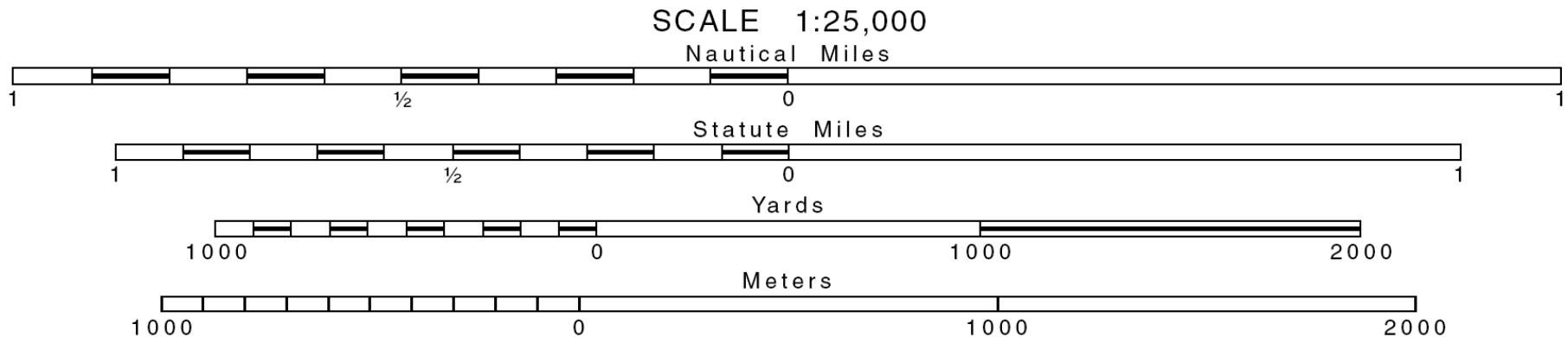
Nautical Mile

1 nautical mile = 1852 meters (exactly)

1 nautical mile \approx one minute of latitude

1 nautical mile \approx 1.15 statute miles

1 nautical mile \approx 6076.1 feet



1 knot = 1 nautical mile per hour

1 knot = 1.852 kph (exactly)

1 knot \approx 1.15 mph

Latitude and Longitude Distances



Latitude:

Parallels are evenly spaced.

1 minute \approx 1 nm.

Longitude:

Meridians converge at poles.

1 minute \approx $\cos(\text{lat}) \times 1$ nm.

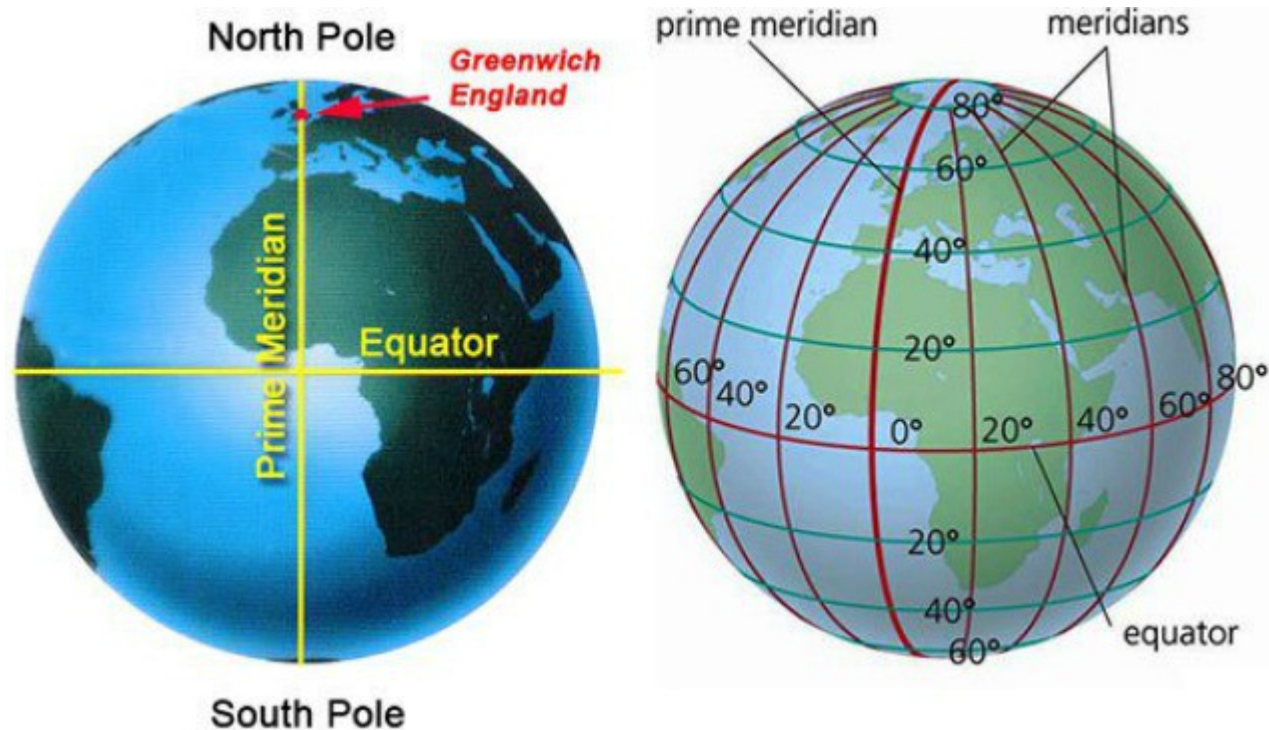
In Boston Harbor:

1 minute longitude \approx .74 nm.

Horizontal Datum

Coordinate system and set of reference points for assigning geographic coordinates (latitude and longitude) to physical locations on the Earth.

Location of Prime Meridian (where longitude = 0)

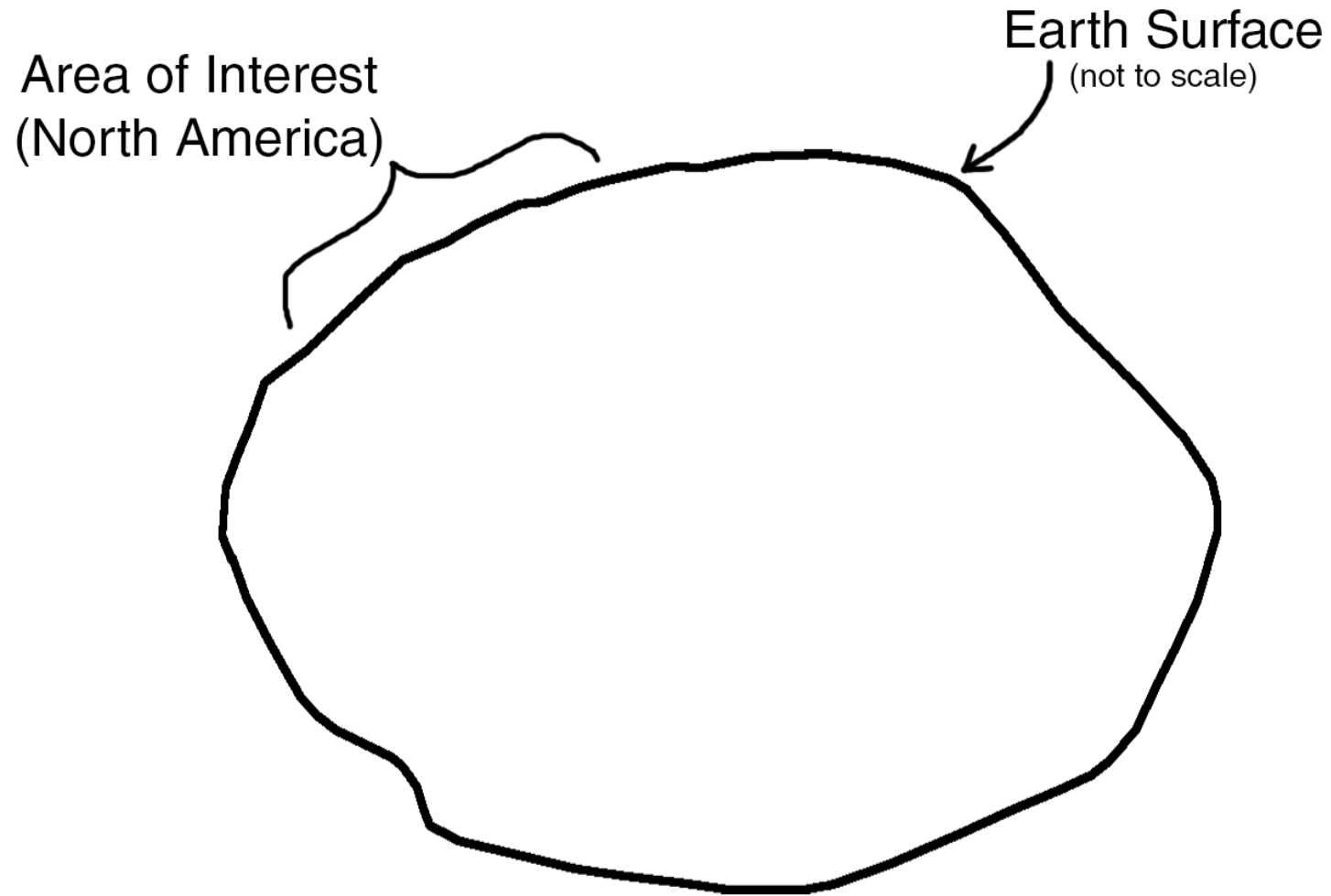


Horizontal Datum

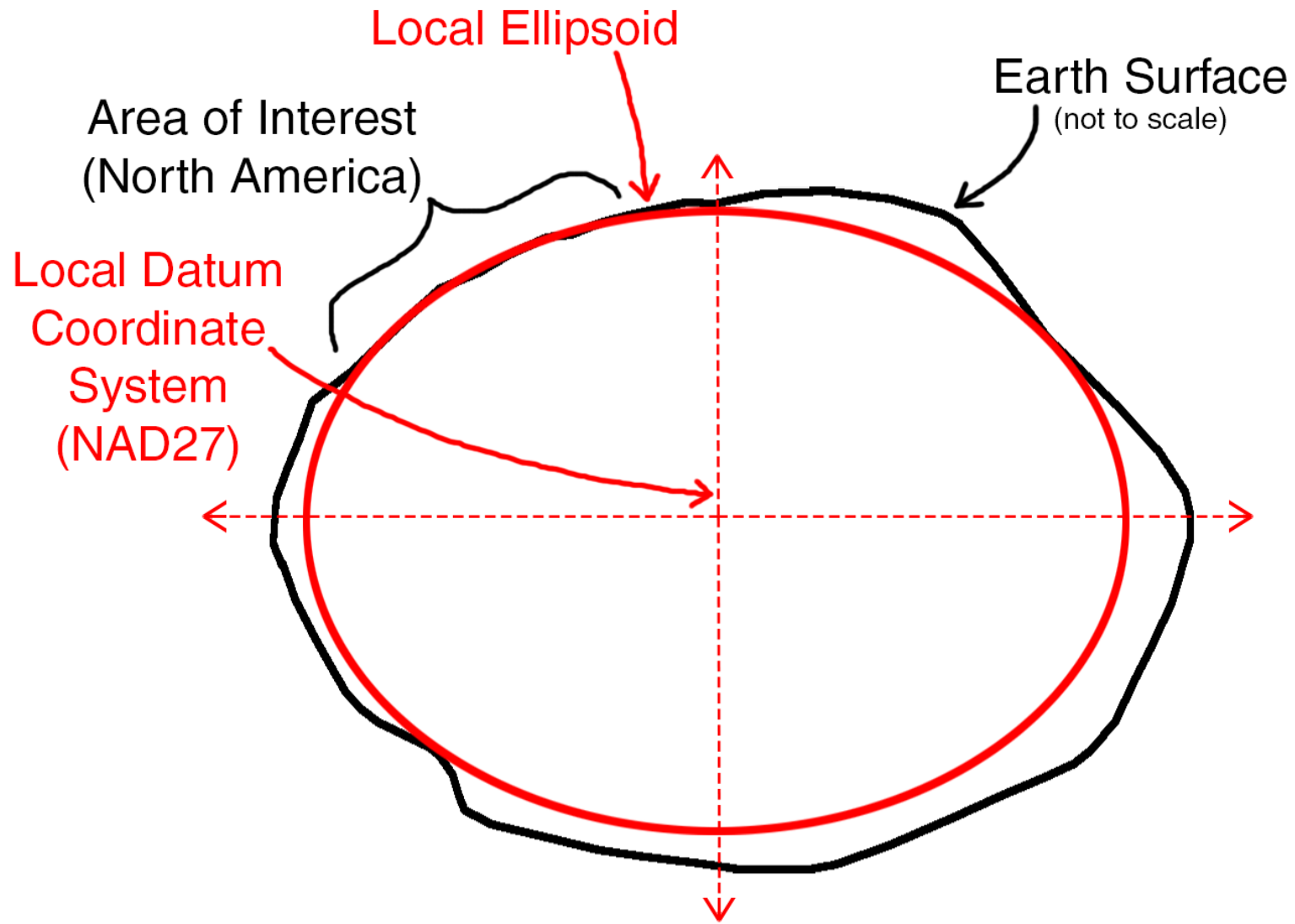
Make sure your GPS and other navigation instruments are using the same Horizontal Datum as your charts.

- World Geodetic System 1984 (WGS84) global standard
- North American Datum 1983 (NAD83) official datum used on all U.S. Charts – varies less than 2 m from WGS84.
- North American Datum 1927 (NAD27) outdated – can vary up to 100 m from WGS84
- Hundreds of other local datums in use around the world.

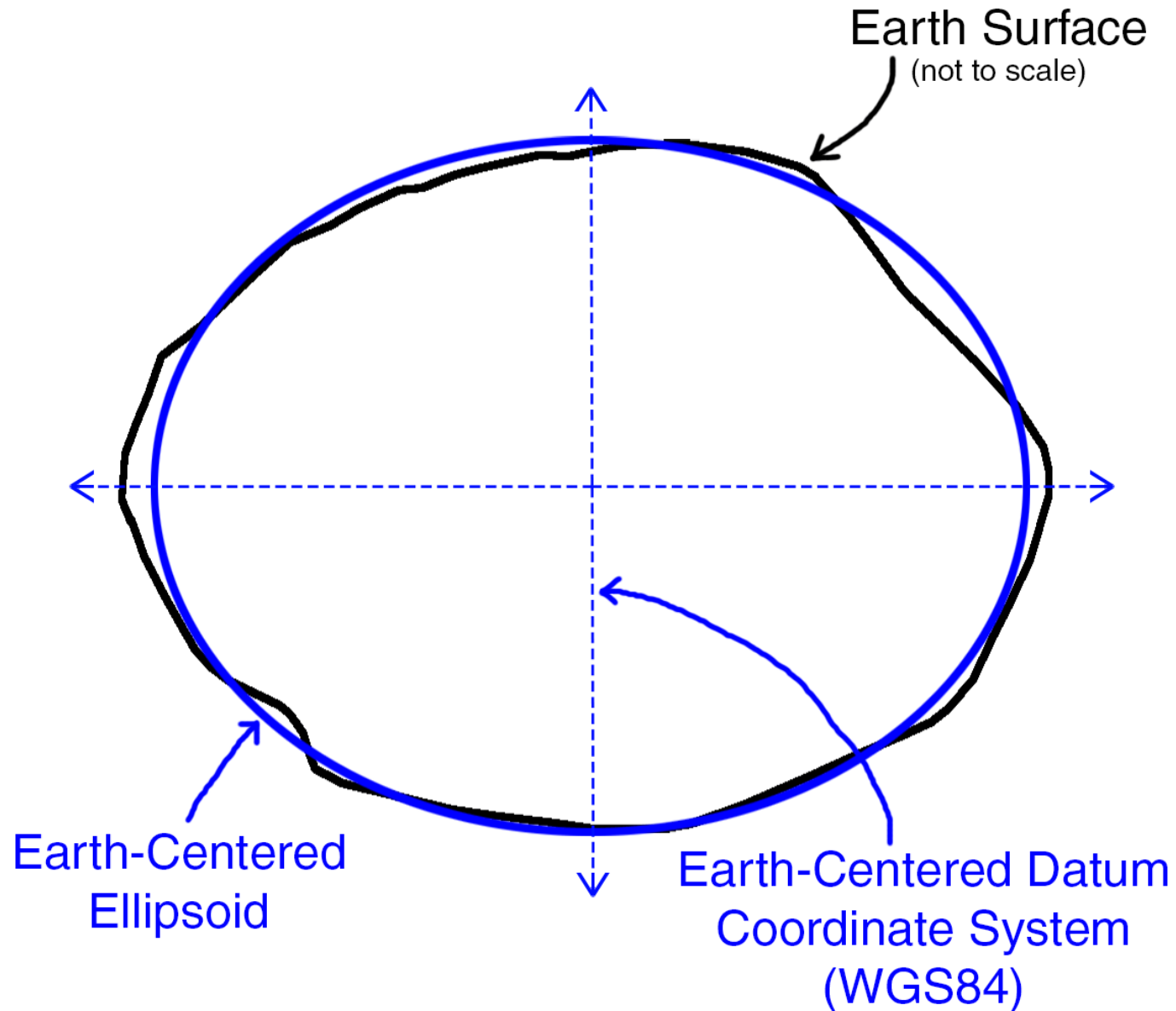
Horizontal Datum



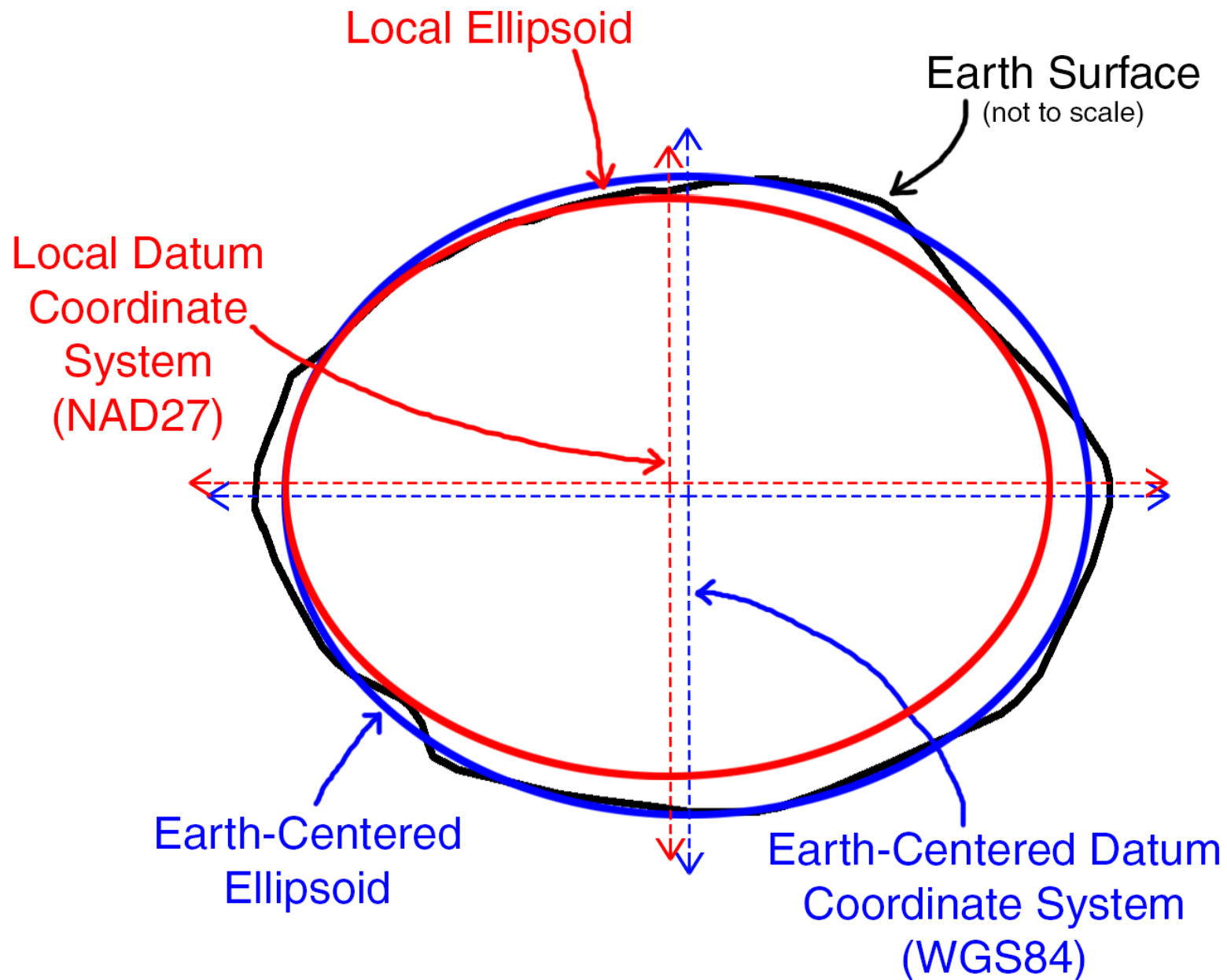
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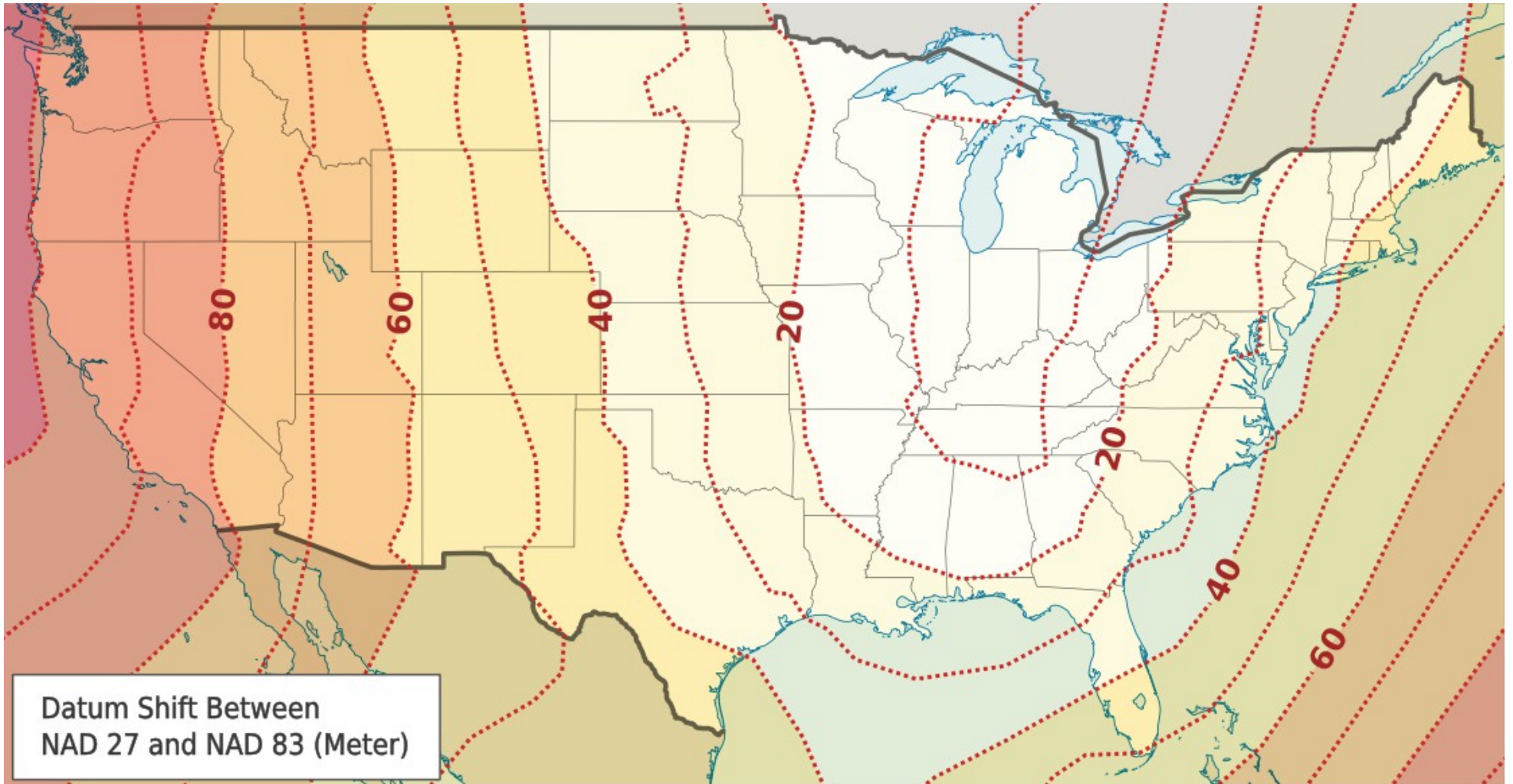
Horizontal Datum



Horizontal Datum



Horizontal Datum

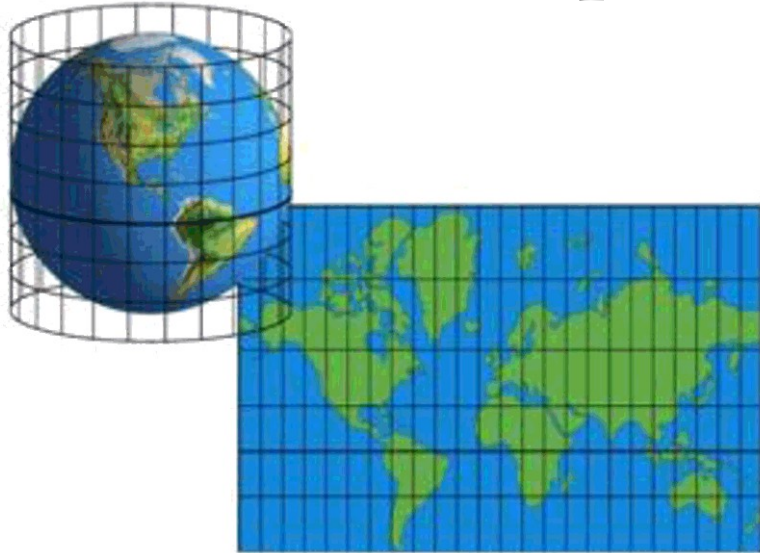


A detailed nautical chart of the Boston Harbor area, showing depth soundings, navigational aids, and geographical features. The chart includes labels for various locations such as Hull, Boston, and various islands and ledges. It features a grid of latitude and longitude lines, depth contours, and various symbols for navigational markers.

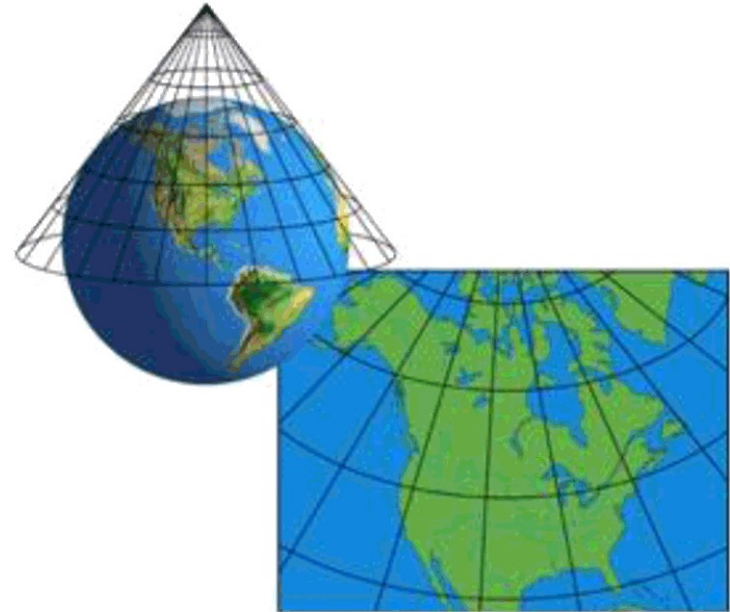
Nautical Charts

- Map Projections (Mercator, etc.)
- Chart Features (legend, scale, etc.)
- Chart Symbols
- Aids to Navigation

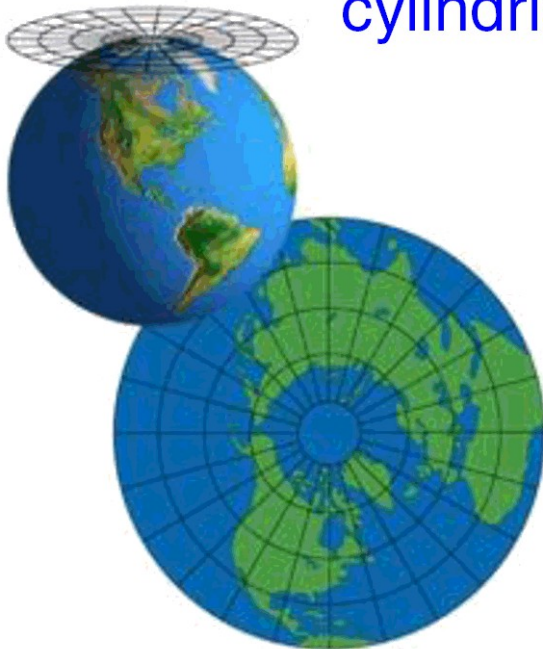
Map Projections



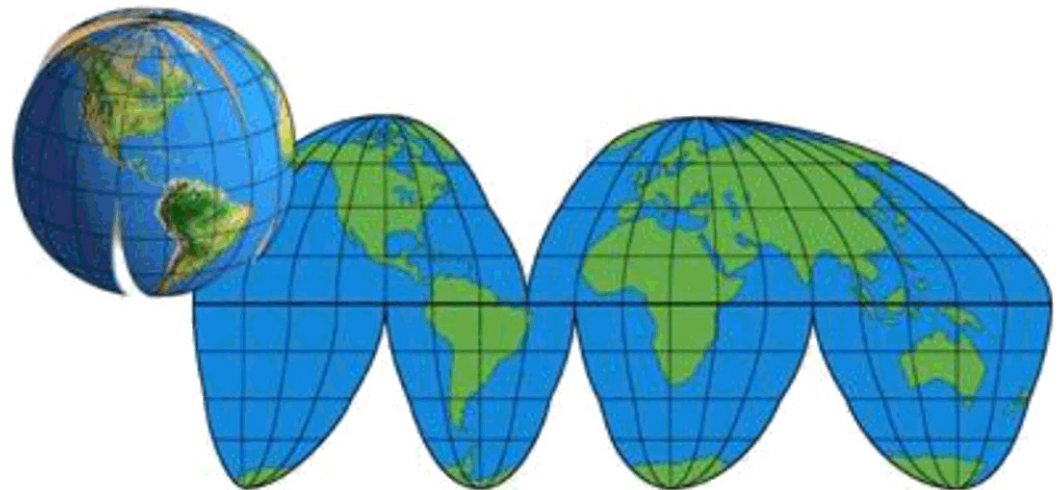
cylindrical projection



conic projection

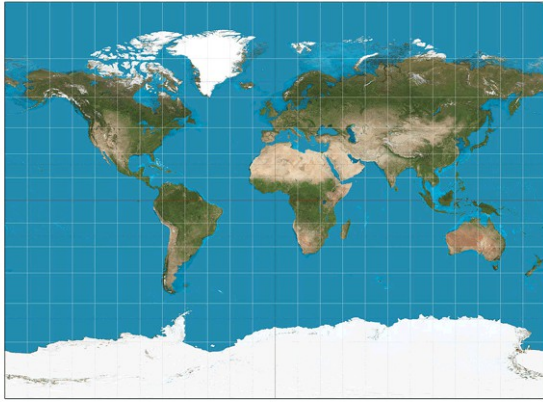


plane projection

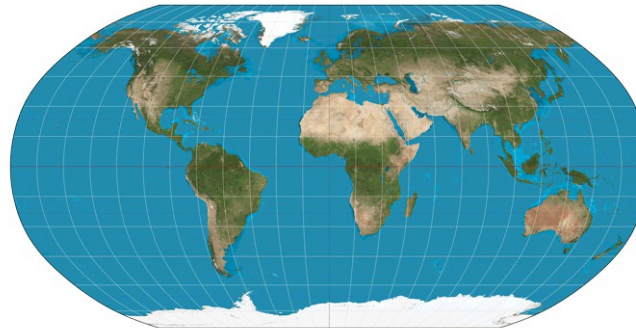


interrupted projection

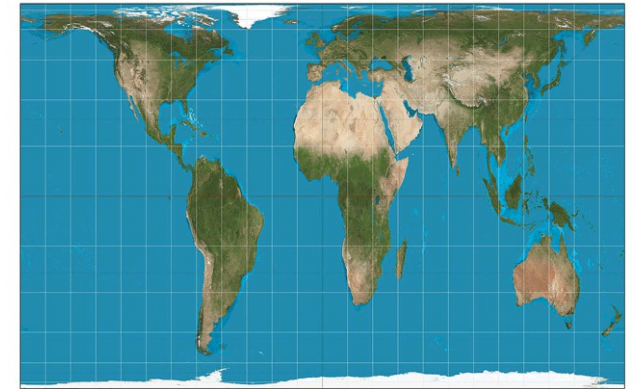
Map Projections



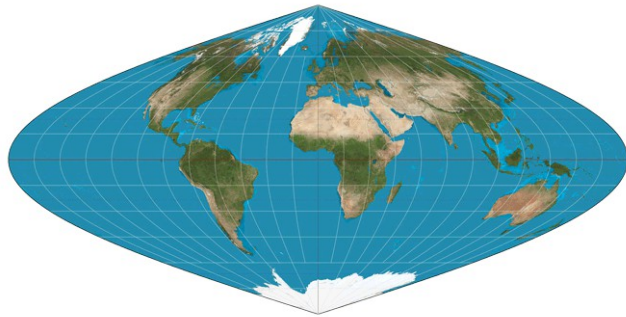
Miller Cylindrical Projection



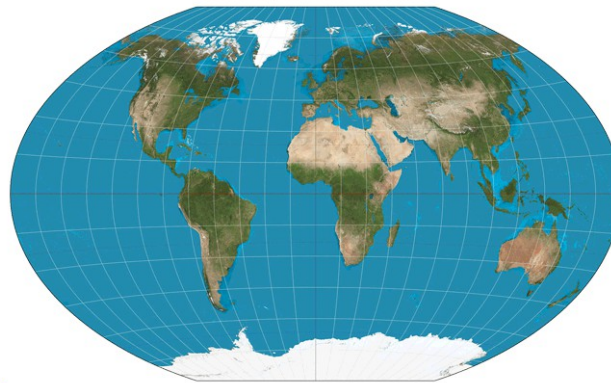
Robinson Projection



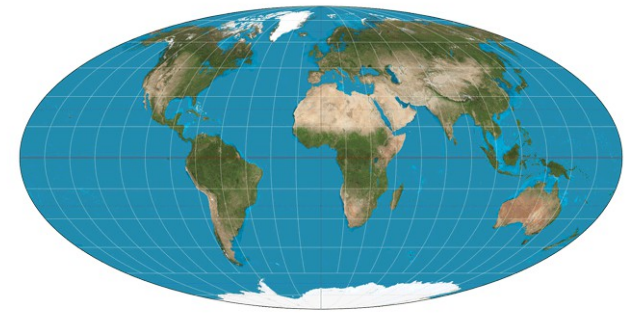
Gall-Peters Projection



Sinusoidal Equal-Area Projection

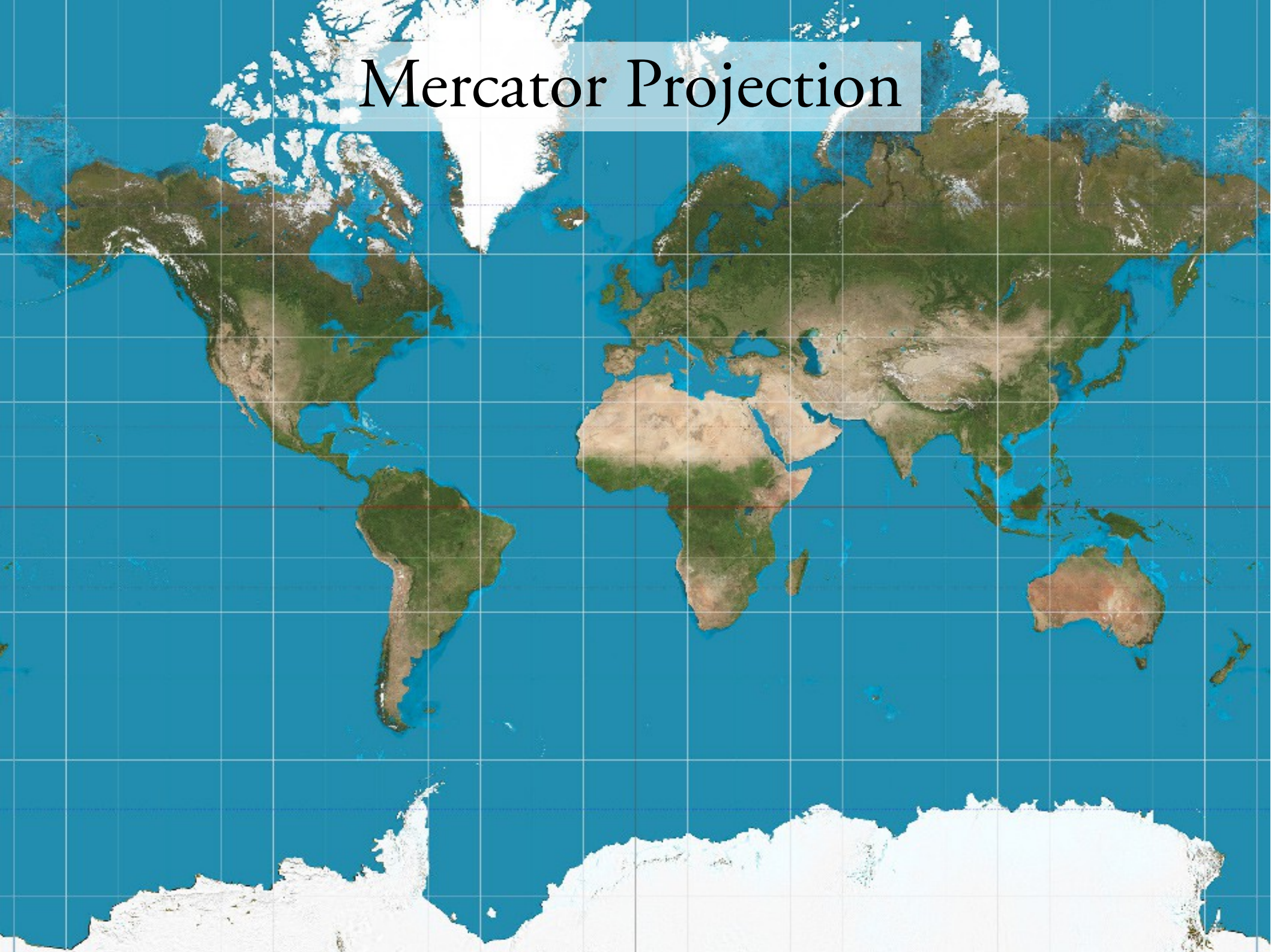


Winkel Tripel Projection



Mollweide Projection

Mercator Projection



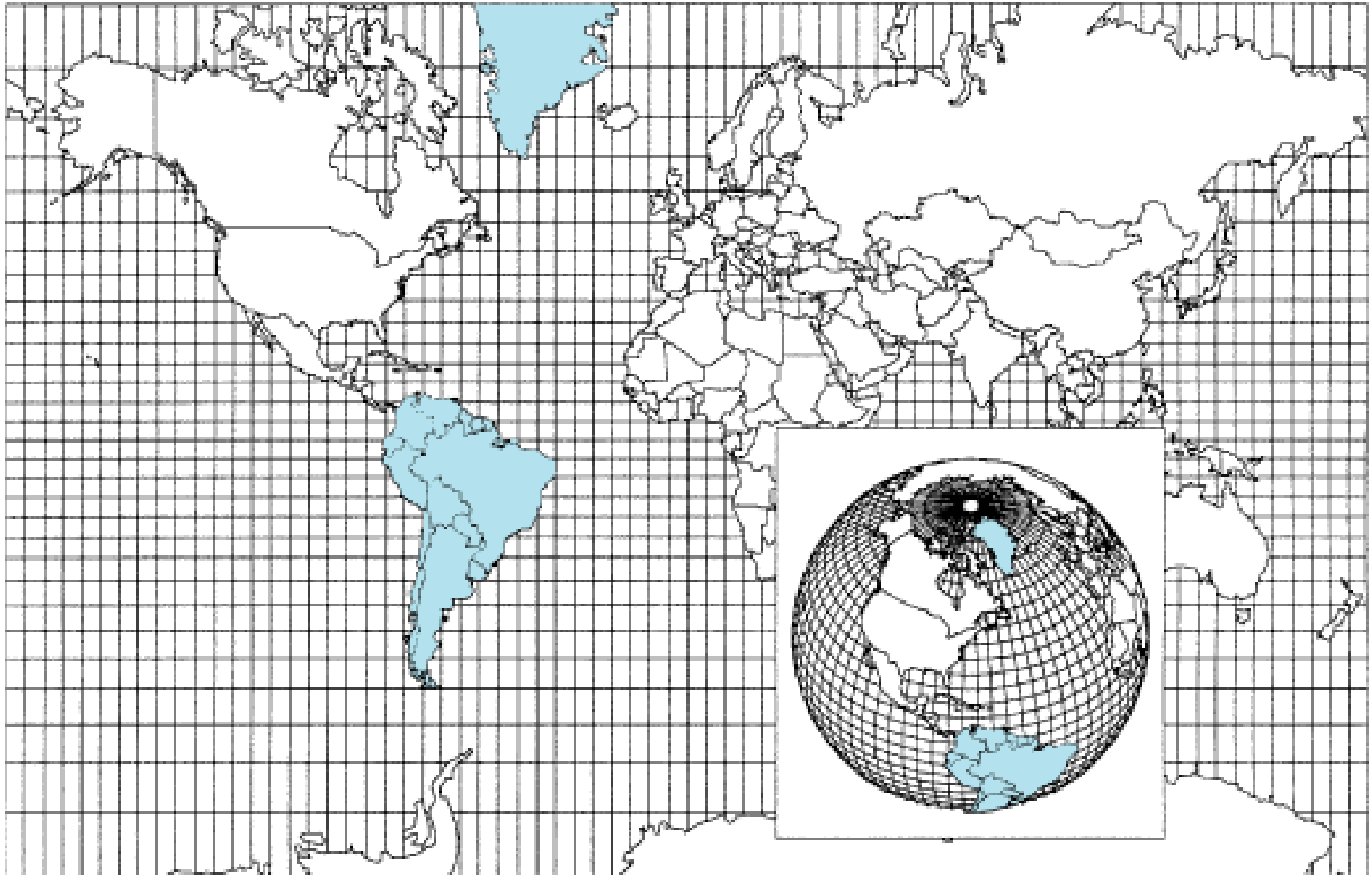
Mercator Projection



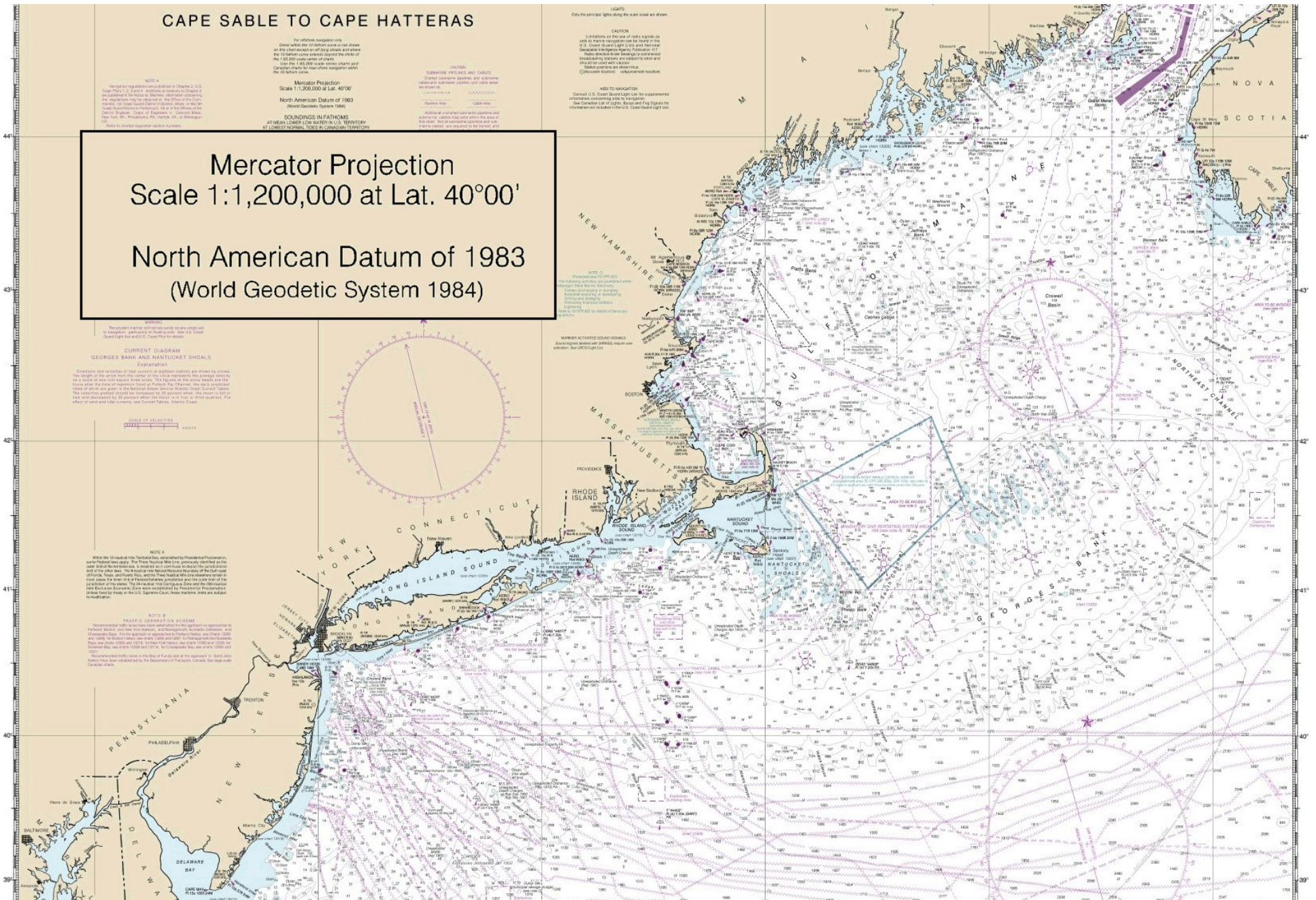
- Scale changes with latitude

Mercator Projection

- Scale changes with latitude



Mercator Projection



Mercator Projection



- Scale changes with latitude
- Meridians and parallels expand at the same rate

Mercator Projection



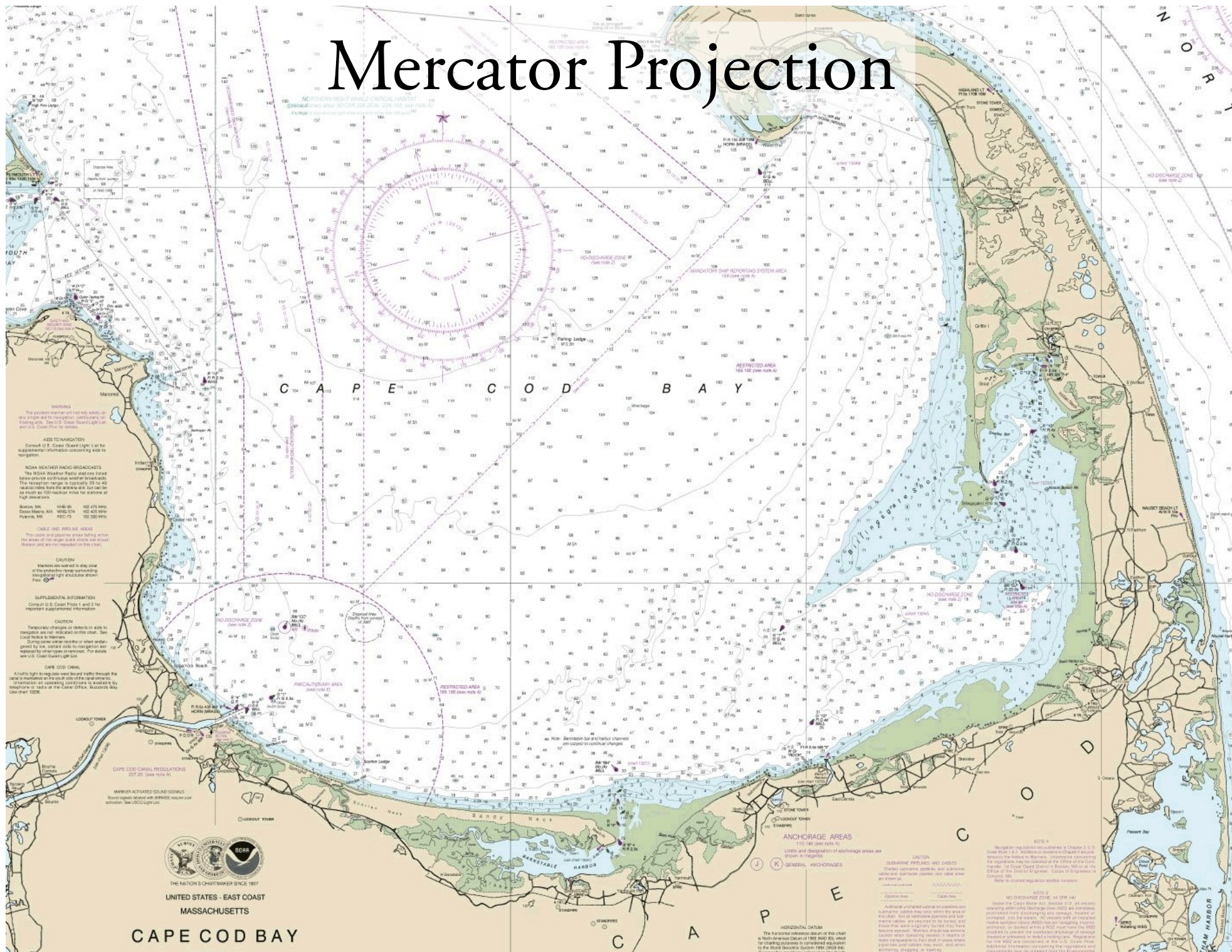
- Scale changes with latitude
- Meridians and parallels expand at the same rate
- Azimuths remain constant

Mercator Projection



- Scale changes with latitude
- Meridians and parallels expand at the same rate
- Azimuths remain constant
- Azimuths can be measured on the chart

Mercator Projection



CAPE COD BAY



THE NATIONAL CHARTPUBLISHER SINCE 1807
UNITED STATES - EAST COAST
MASSACHUSETTS

ANCHORAGE AREAS
Limits and designations of anchorage areas are shown in triangles.

SUBMERGED OBSTACLES AND CAUTIONS
Charted submerged obstructions and cautions are shown in triangles.

GENERAL ANCHORAGES
Limits and designations of anchorage areas are shown in triangles.

CAUTION
Charted submerged obstructions and cautions are shown in triangles.

GENERAL ANCHORAGES
Limits and designations of anchorage areas are shown in triangles.

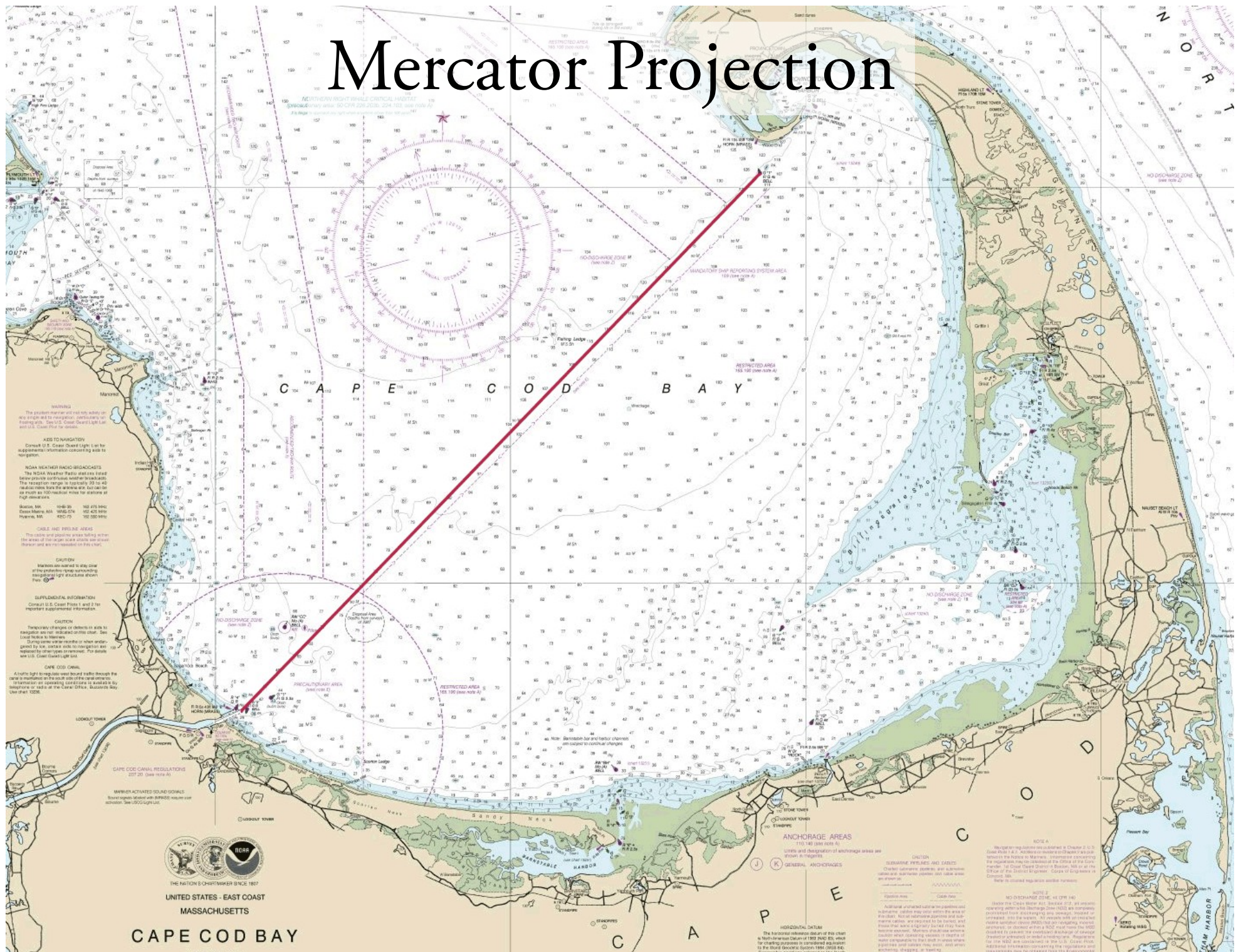
HORIZONTAL DATUM
The horizontal reference datum of this chart is North American Datum of 1983 (NAD 83), which for all practical purposes is considered equivalent to the World Geodetic System 1984 (WGS 84). Some chart features reference to the datum.

NOTE 1
NO DISCHARGE ZONE - 45 CFR 140
Under the Clean Water Act, Section 312, all vessels operating within the Discharge Zone (DDZ) are prohibited from discharging oil or other pollutants into the waters. All vessels with an MSD are required to have an MSD plan on board and to follow the procedures in the MSD plan in the event of an oil spill. For more information on the MSD plan, contact the U.S. Coast Guard at 202-267-2000 or visit the website at www.uscg.gov.

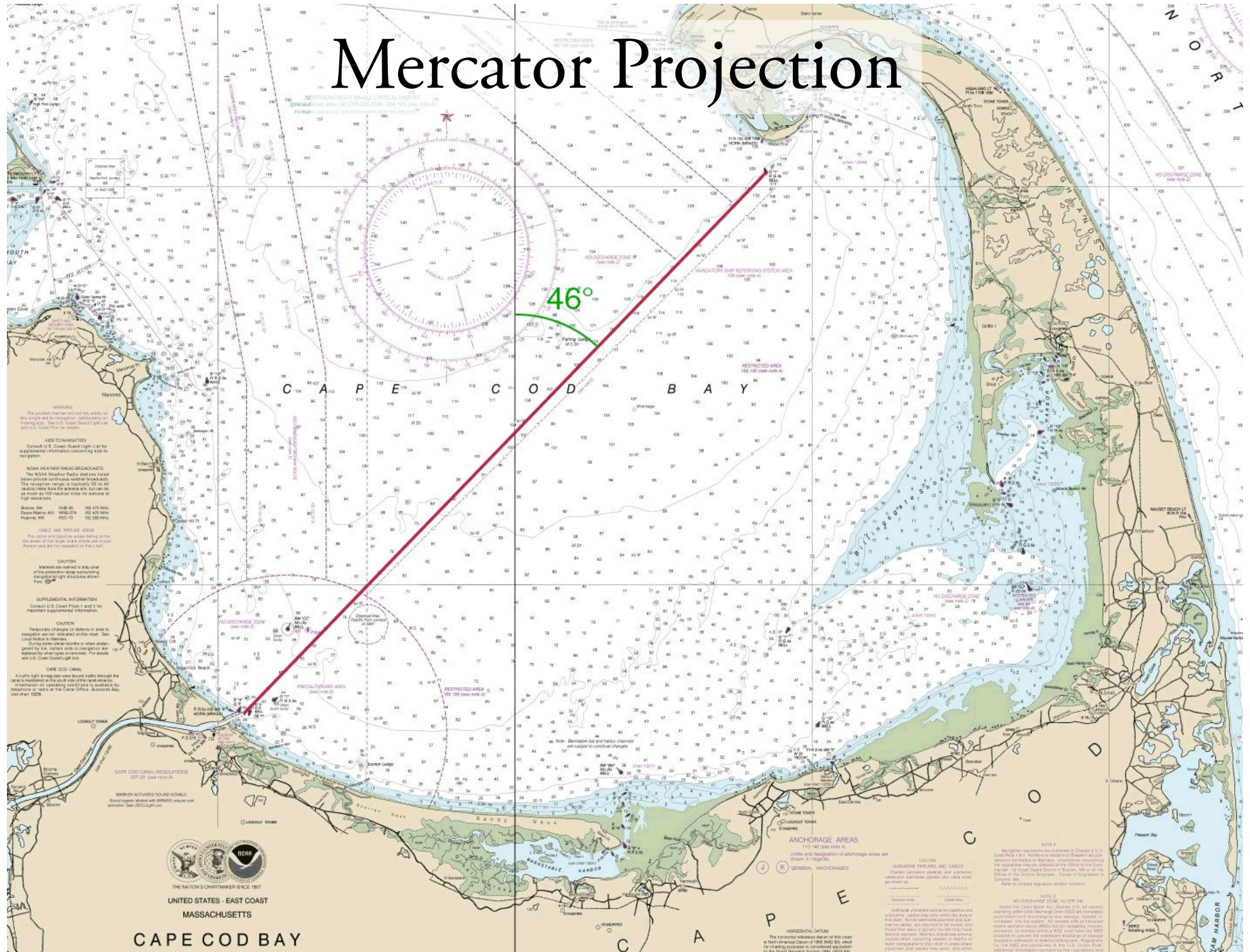
NOTE 2
NO DISCHARGE ZONE - 45 CFR 140
Under the Clean Water Act, Section 312, all vessels operating within the Discharge Zone (DDZ) are prohibited from discharging oil or other pollutants into the waters. All vessels with an MSD are required to have an MSD plan on board and to follow the procedures in the MSD plan in the event of an oil spill. For more information on the MSD plan, contact the U.S. Coast Guard at 202-267-2000 or visit the website at www.uscg.gov.

NOTE 3
NO DISCHARGE ZONE - 45 CFR 140
Under the Clean Water Act, Section 312, all vessels operating within the Discharge Zone (DDZ) are prohibited from discharging oil or other pollutants into the waters. All vessels with an MSD are required to have an MSD plan on board and to follow the procedures in the MSD plan in the event of an oil spill. For more information on the MSD plan, contact the U.S. Coast Guard at 202-267-2000 or visit the website at www.uscg.gov.

Mercator Projection



Mercator Projection



46°

CAPE COD BAY



THE NATION'S CHARTMAKER SINCE 1817
UNITED STATES - EAST COAST
MASSACHUSETTS

ANCHORAGE AREAS
Limits and designations of anchorage areas are shown in triangles.

SOUNDING AREAS AND CANALS
Charted soundings, depths, and water areas are shown in meters.

NOTE 1
NO DISCHARGE ZONE - 45 17N 140 00W
Within the Cape Cod Bay and Buzzards Bay, all vessels operating within the Discharge Zone (DDZ) are prohibited from discharging any oil or oil-bearing wastes into the water. All vessels with an oil spill response plan on board are required to be on board and ready to respond at all times. For more information, see the DDZ notice posted on the NOAA website.

GENERAL ANCHORAGES
General anchorage areas are shown in triangles.

HORIZONTAL DATUM
The horizontal datum used for this chart is North American Datum of 1983 (NAD 83), which is the datum used for all geographic information system (GIS) data. For more information, see the NOAA website.



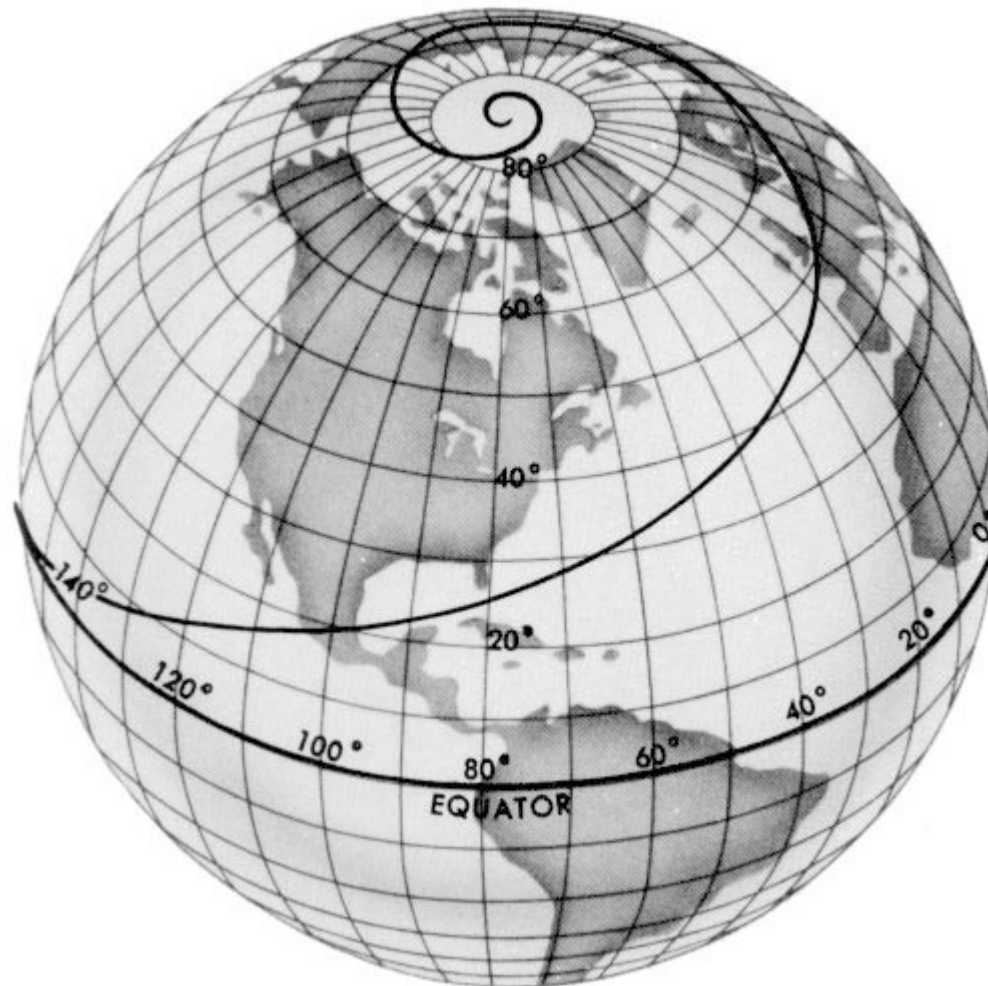
Mercator Projection



- Scale changes with latitude
- Meridians and parallels expand at the same rate
- Azimuths remain constant
- Azimuths can be measured on the chart
- Rhumb lines are straight lines

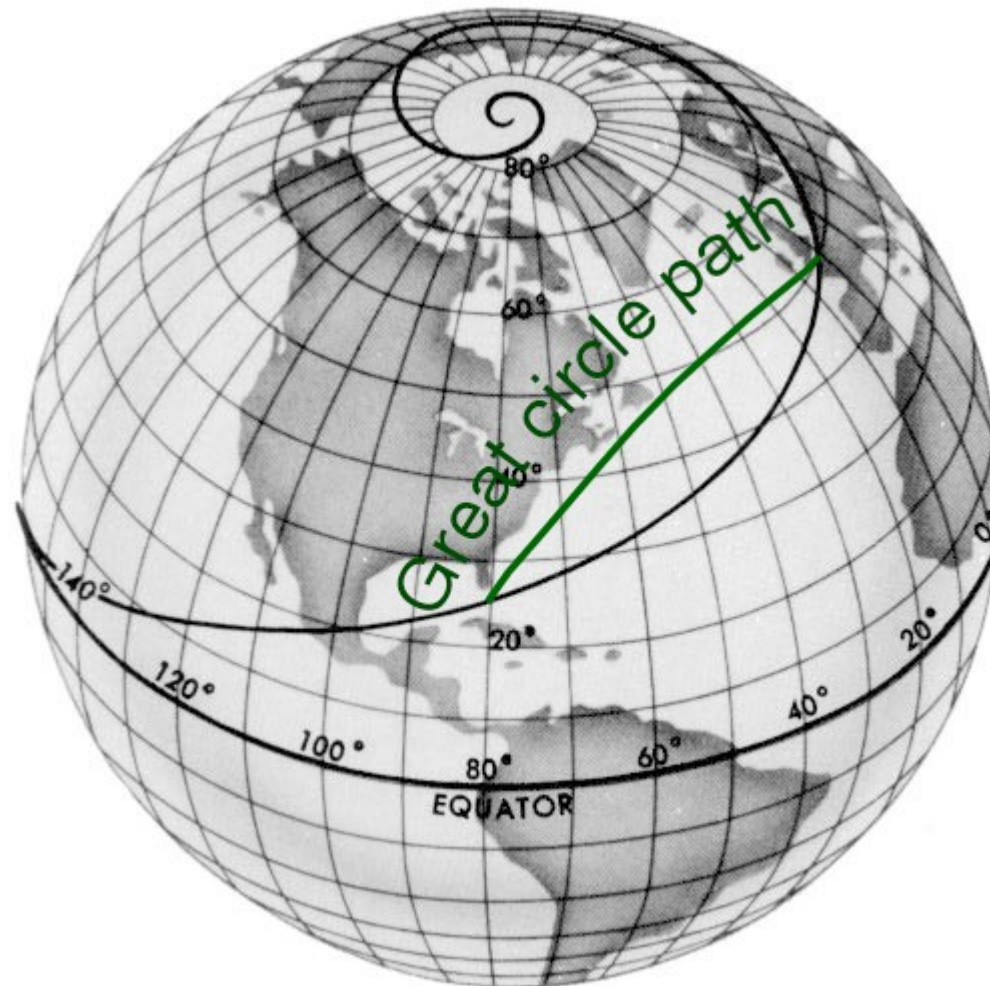
Mercator Projection

- A *rhumb line* is a path of constant azimuth. (also called a *loxodrome*).



Mercator Projection

- The shortest distance between two points on a sphere is along a great circle.

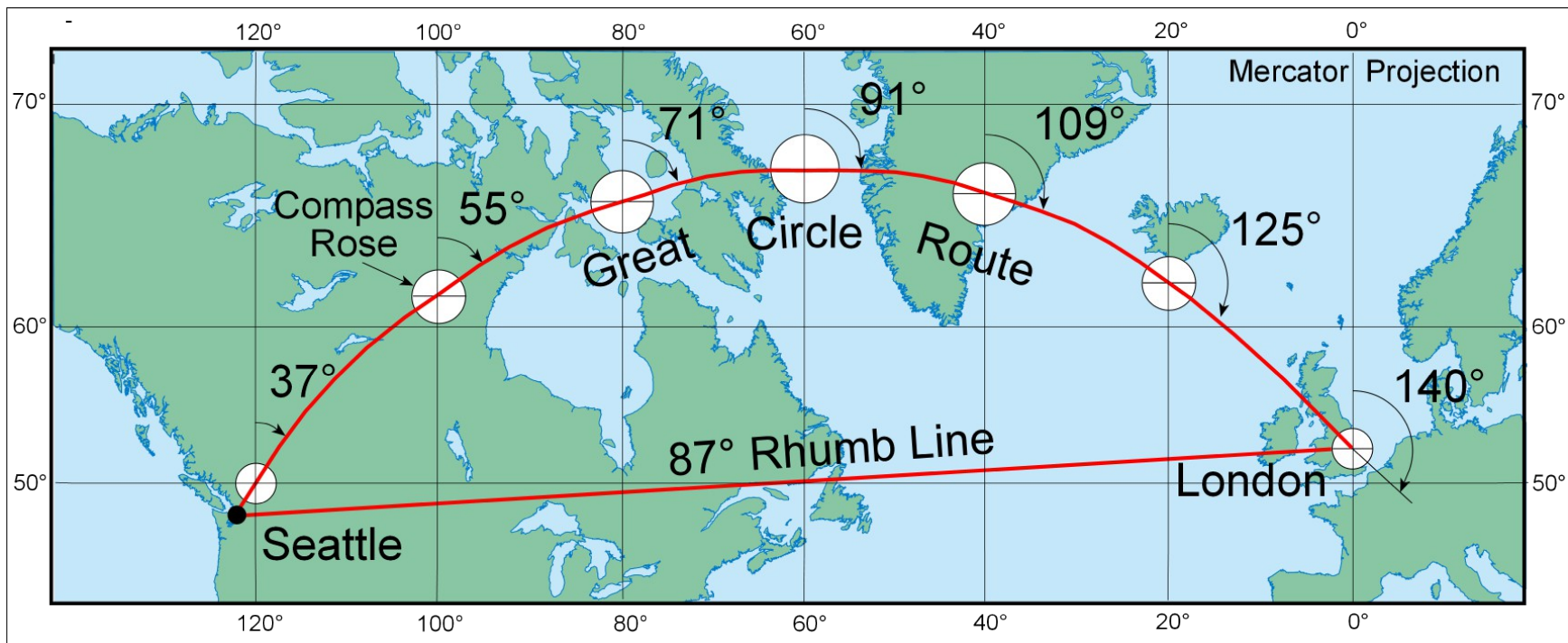
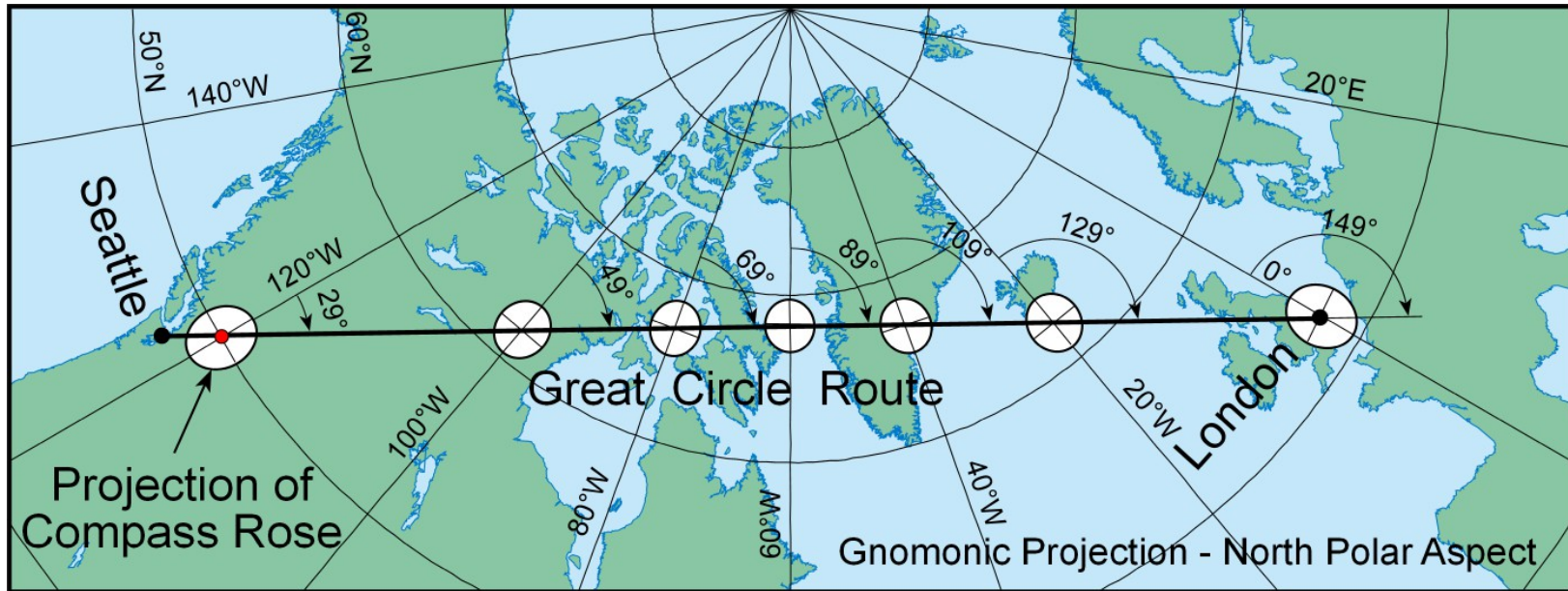


Mercator Projection



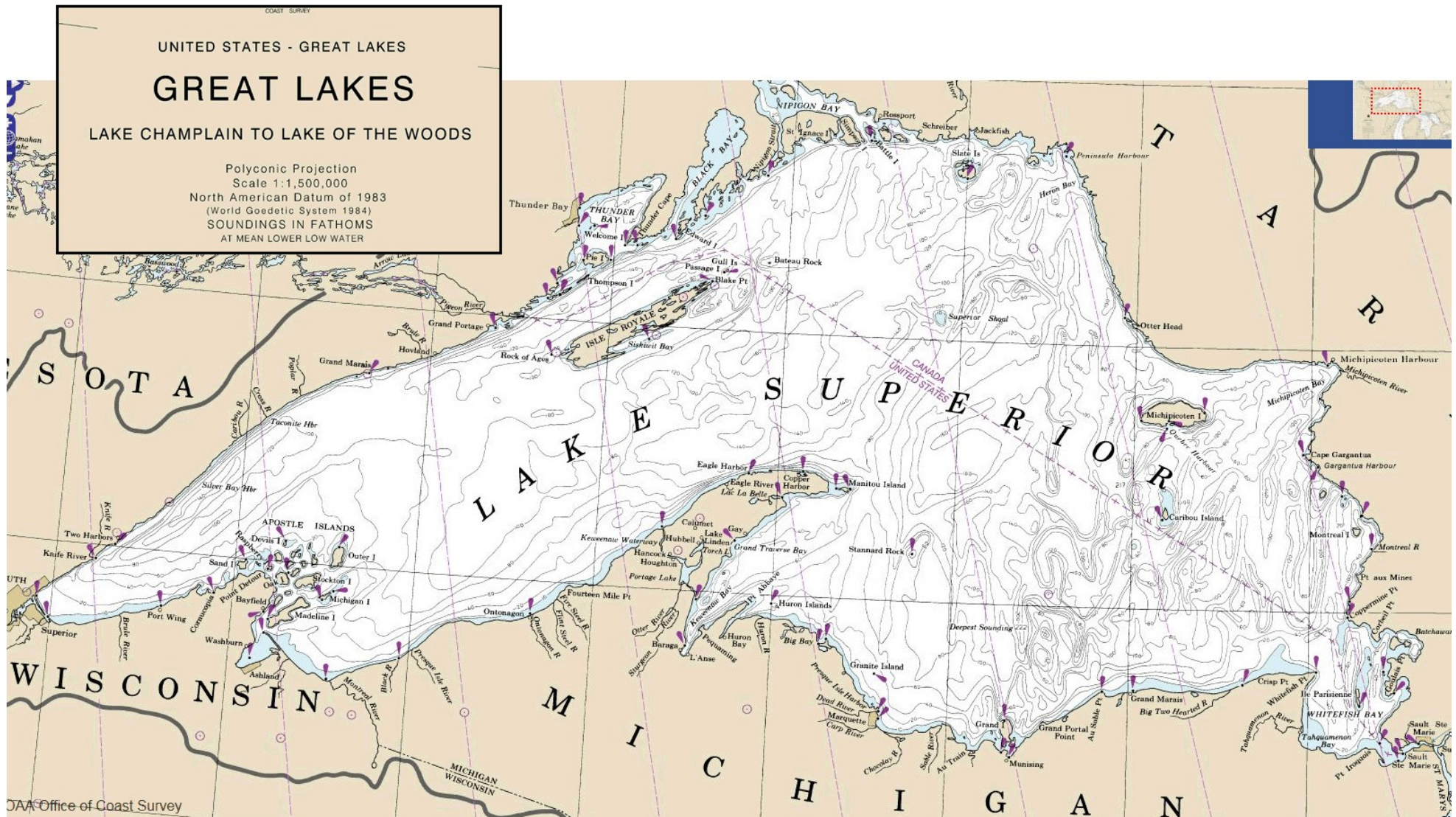
- Scale changes with latitude
- Meridians and parallels expand at the same rate
- Azimuths remain constant
- Azimuths can be measured on the chart
- Rhumb lines are straight lines
- Great circles are curved

Mercator Projection



Polyconic Projection

Used on many charts of the Great Lakes



A detailed nautical chart of Hull Harbor, Massachusetts, showing depth contours, soundings, and various navigational features. The chart includes labels for 'HULL BAYS', 'ALERTON HARBOR', and 'SUNSET LEDGE'. It features a grid of latitude and longitude lines, depth soundings in fathoms, and various symbols for navigational hazards and structures. The chart is overlaid with a list of nautical chart features.

Nautical Chart Features

- Title block
- Scales
- Chart number and edition
- Geographic features (coastline, landmarks)
- Hydrographic features (depth contours, soundings)
- Compass rose
- Symbols and abbreviations
- Warnings and local information

Chart Title Block

UNITED STATES - EAST COAST

MASSACHUSETTS

BOSTON HARBOR

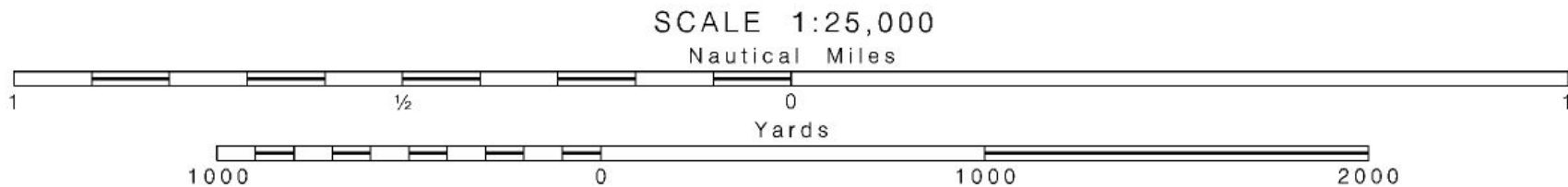
Mercator Projection
Scale 1:25,000 at Lat. 42°19'

North American Datum of 1983
(World Geodetic System 1984)

SOUNDINGS IN FEET
AT MEAN LOWER LOW WATER

Chart Scales

- Representative fraction (e.g. 1:80,000)
- A statement (e.g. “one inch equals 30 miles”)
- Graphic scale



- Latitude index along each side of the chart

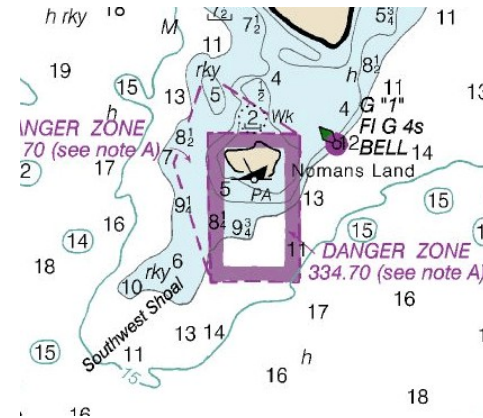
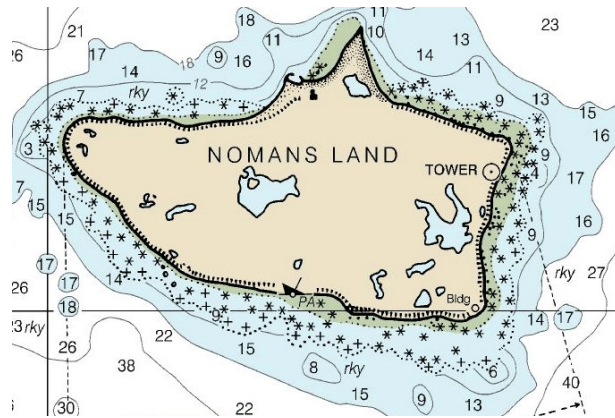
42°
30'

25'

Chart Scales

- “Large Scale” vs. “Small Scale”

Refers to the size of the printed images on the chart:



- 73,913 inches per nautical mile
1:72,000 scale → 1 nm. ≈ 1 inch
1:25,000 scale → 1 nm. ≈ 3 inches
1:800,000 scale → 1 nm. ≈ 1/10 inch

Chart Scales

- Sailing Charts
very small scale – 1:600,000 or greater
- General Charts
1:150,000 to 1:600,000
- Coastal Charts
1:50,000 to 1:150,000
- Harbor Charts
large scale – 1:50,000 or less

Chart Number and Edition

64th Ed., Feb. / 11

13270

CAUTION

This chart has been corrected from the Notice to Mariners (NM) published weekly by the National Geospatial-Intelligence Agency and the Local Notice to Mariners (LNM) issued periodically by each U.S. Coast Guard district to the dates shown in the lower left hand corner. Chart updates corrected from Notice to Mariners published after the dates shown in the lower left hand corner are available at nauticalcharts.noaa.gov.

Last Correction: 12/15/2015. Cleared through:

LNM: 5015 (12/15/2015), NM: 5215 (12/26/2015), CHS: 1115 (11/27/2015)

- Chart number: 5 digits
- Above number is edition number and print date
- Corrections to charts are published in Notices to Mariners (NM) and Local Notices to Mariners (LNM)
- New corrections should be applied to chart



U.S. Department
of Homeland Security
**United States
Coast Guard**

LOCAL NOTICE TO MARINERS

District: 1

Week: 52/15

COASTAL WATERS FROM EASTPORT, MAINE TO SHREWSBURY, NEW JERSEY

NOTES:

- (1) Unless otherwise indicated, missing and destroyed structures are presumed to be in the immediate vicinity of assigned position. Mariners should proceed with caution.
- (2) The Local Notice to Mariners is a weekly edition.
- (3) Inquiries, published articles or Information: mail to: LNM@uscg.mil
- (4) The U.S. Coast Pilot supplements the navigational information shown on nautical charts.
- (5) The Coast Pilot, along with its corrections, are available online at <http://www.nauticalcharts.noaa.gov/nsd/cpdownload.htm> .

The Local Notice to Mariners is available online at <http://www.navcen.uscg.gov/?pageName=lnmDistrict®ion=1>
The updated 2015 Light List is available online at: <http://www.navcen.uscg.gov/?pageName=lightListWeeklyUpdates>
Information on Private Aids to Navigation is available at: <http://www.uscg.mil/d1/prevention/NavInfo/navinfo/paton.htm>
Reports of Channel conditions can be found at the Army Corps of Engineers website at:

- NM is for large ships, LNM is for all boats
- Published weekly, number refers to week/year
- Subscribe or download at <http://navcenter.uscg.gov>

Chart Geographic Features

- Land: tan

- Intertidal Zone: green

- Water: white

- Shallow Water: blue

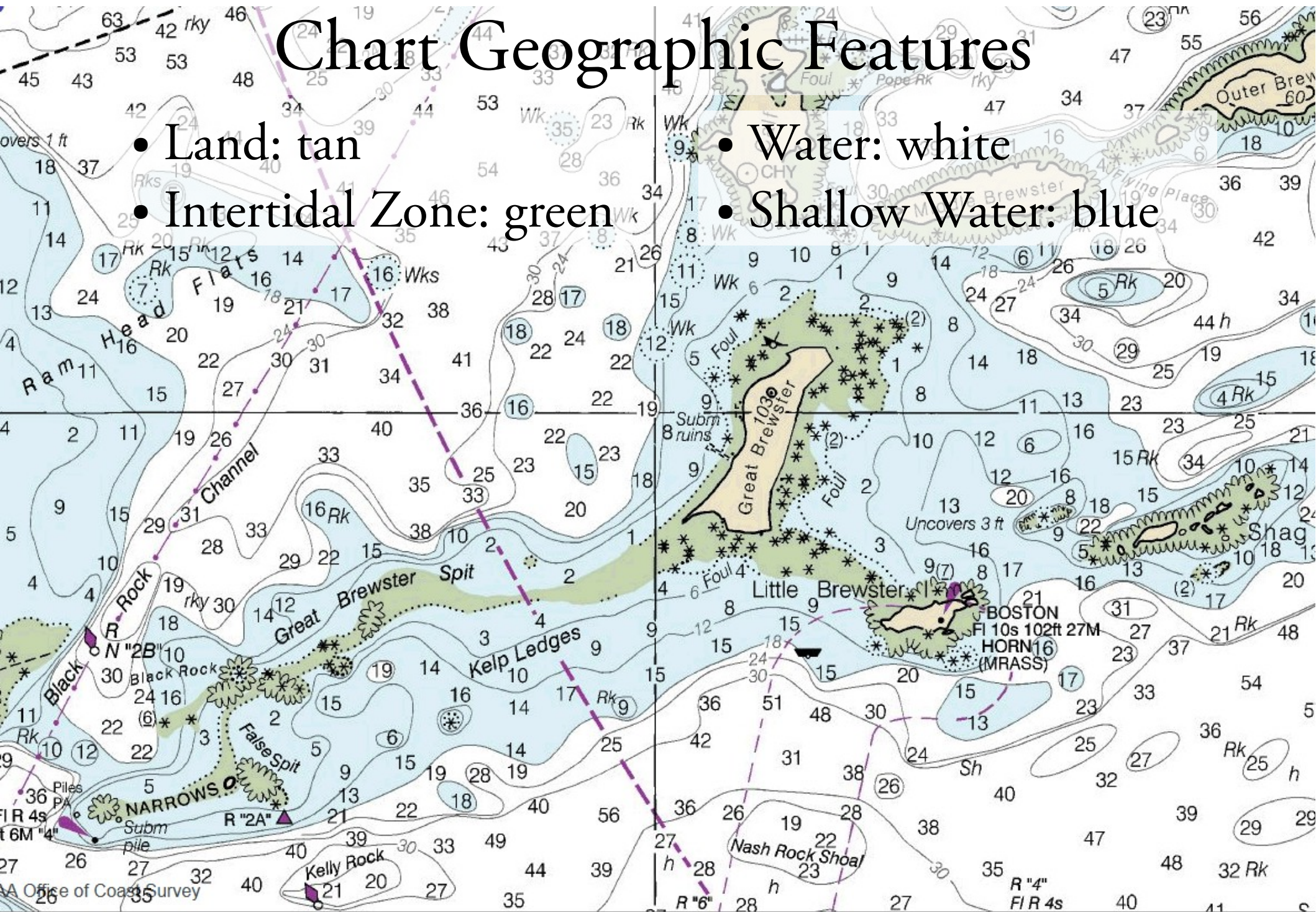


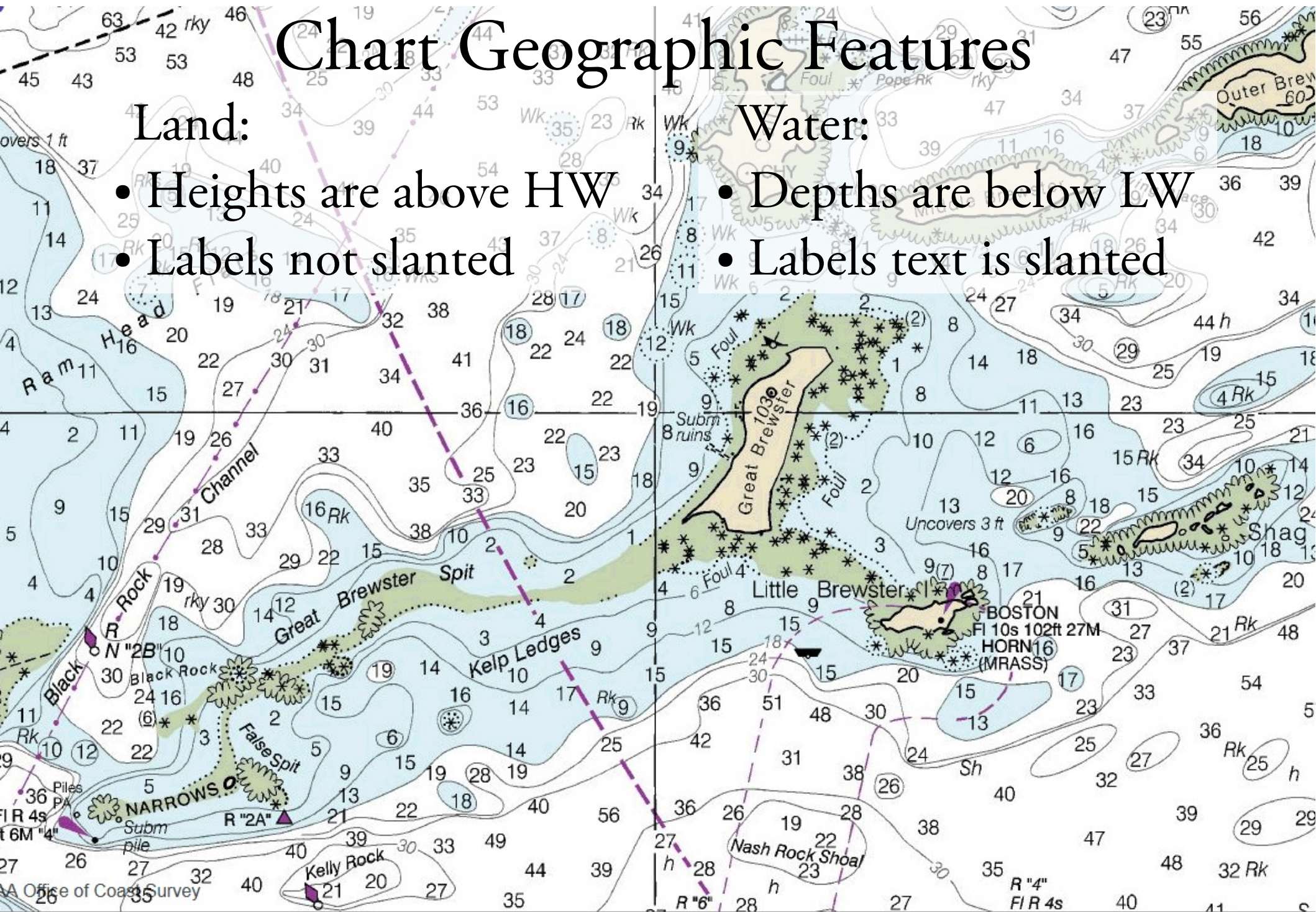
Chart Geographic Features

Land:

- Heights are above HW
- Labels not slanted

Water:

- Depths are below LW
- Labels text is slanted



Compass Rose

Outside ring: True, Inside ring: Magnetic

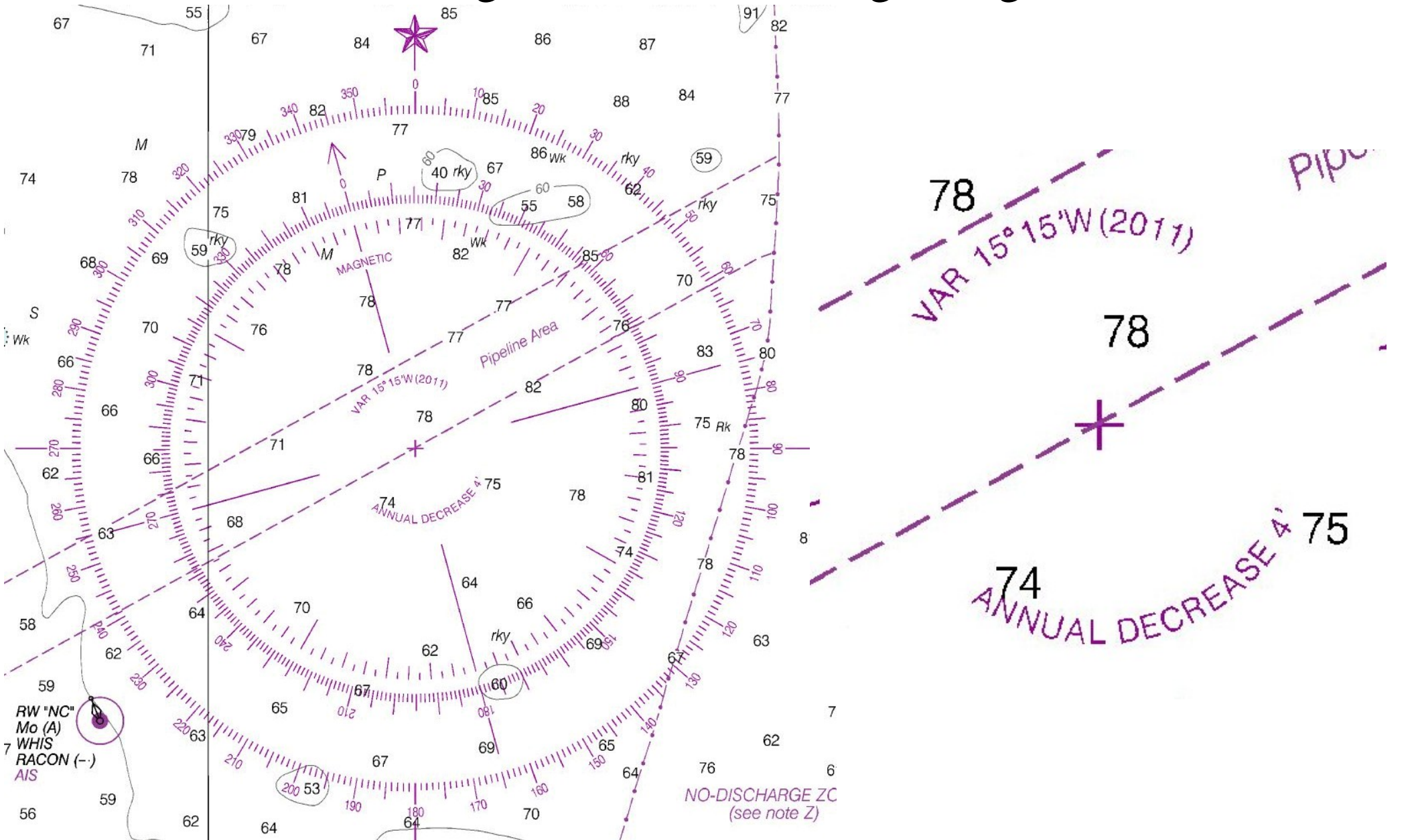
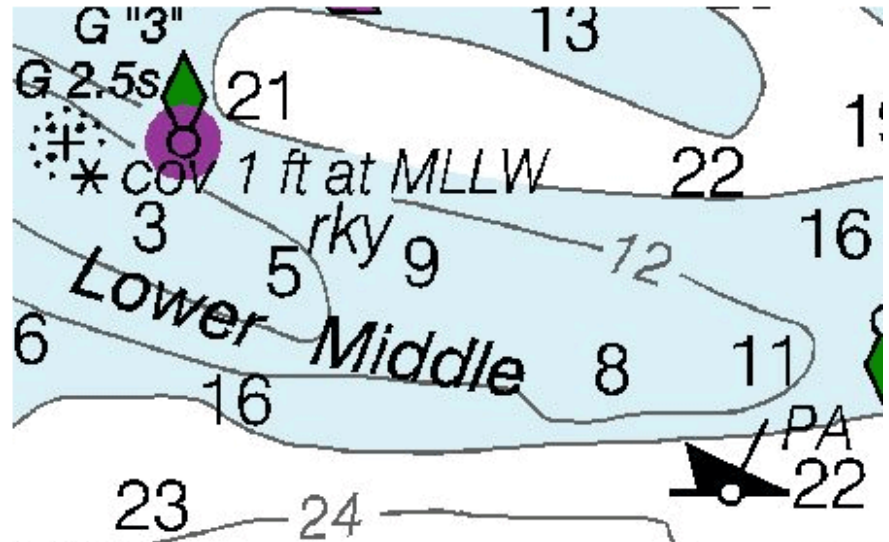
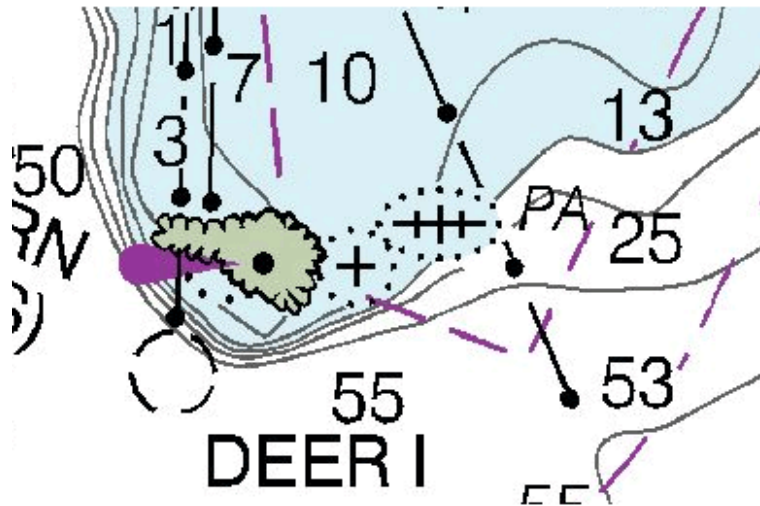


Chart Symbols

- + Rock (below water at low tide)
- ⊞ Rock (at low water level)
- * Rock (above water at low tide)
- ⚓ Wreck (above water at low tide)
- ⦶ Wreck (below water at low tide)
- ◊ Bouoy
- ◊ Lighted Bouoy
- Light



Lower Middle Channel

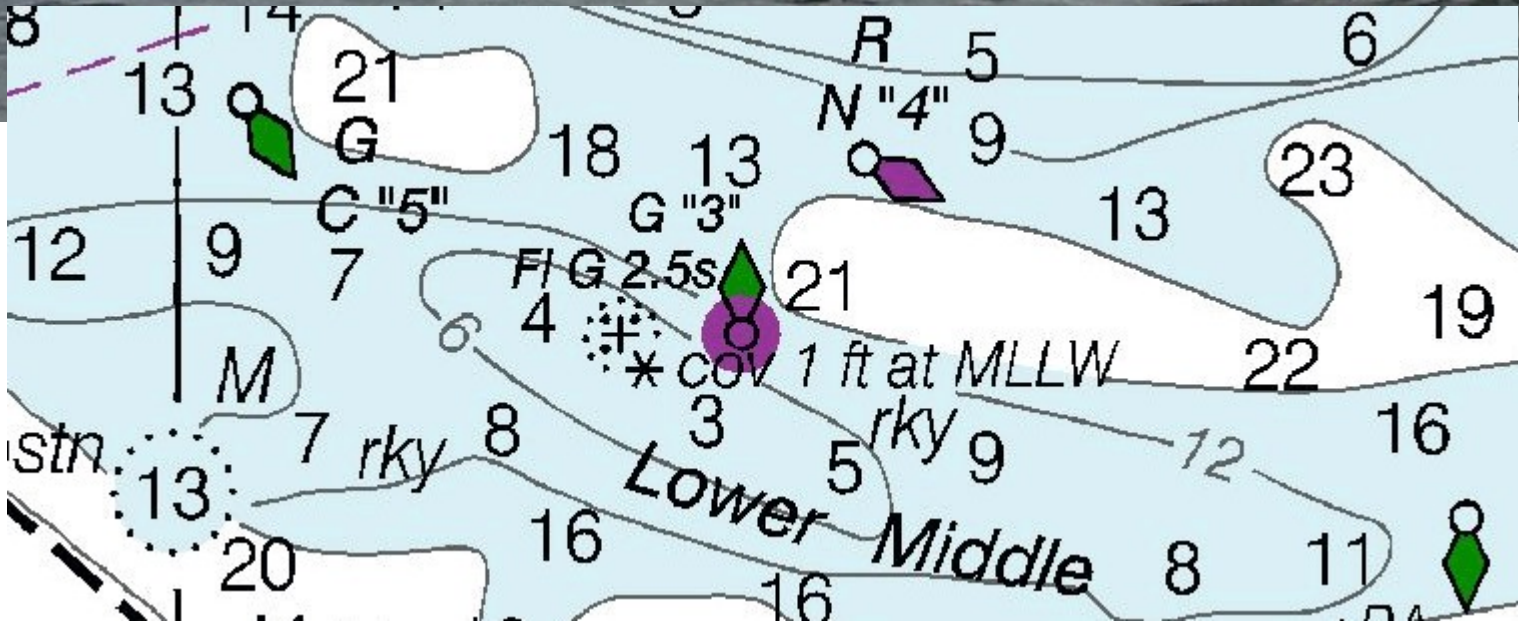
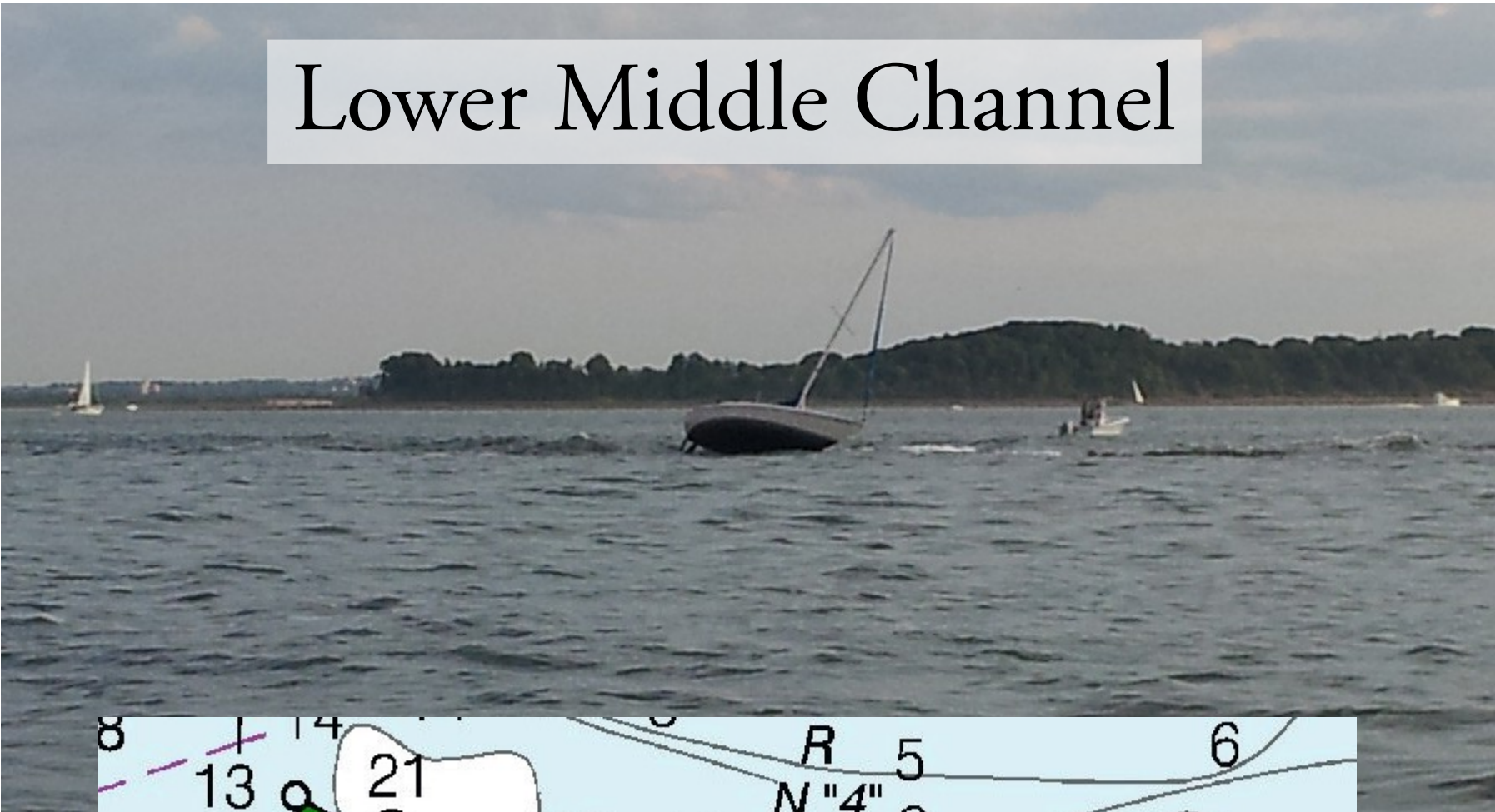


Chart Symbols

All chart symbols are listed in “Chart No. 1”

Rocks, Wrecks, Obstructions, Aquaculture **K**

No.	INT	Description	NOAA	NGA	Other NGA	ECDIS	
General							
1		Danger line: A danger line draws attention to a danger which would not stand out clearly enough if represented solely by its symbol (e.g. isolated rock) or delimits an area containing numerous dangers, through which it is unsafe to navigate					Obstruction, depth not stated Obstruction which covers and uncovers Underwater hazard with depth of 20 meters or less Isolated danger of depth less than the safety contour Foul area, not safe for navigation
2		Swept by wire drag or diver					Swept sounding, less than or equal to safety depth Swept sounding, greater than safety depth
3		Depth unknown, but estimated to have a safe clearance to the depth shown				ECDIS displays safe clearance depths in the same manner as known depths.	
Rocks							
Plane of Reference for Heights → H			Plane of Reference for Depths → H				
10		Rock (islet) which does not cover, height above height datum					Land as a point at small scale Land as an area, with an elevation or control point
11		Rock which covers and uncovers, height above chart datum					Rock which covers and uncovers or is awash at low water Underwater hazard which covers and uncovers with drying height Isolated danger of depth less than the safety contour
12		Rock awash at the level of chart datum					Rock which covers and uncovers or is awash at low water Underwater hazard which covers and uncovers Isolated danger of depth less than the safety contour

Chart Warnings & Local Information

SMALL CRAFT WARNINGS

Year round small-craft warnings will be displayed during daytime only on Metropolitan District Commission Police Patrol Boats underway in Inner Boston Harbor from Nantasket Beach (42° 16.2' N, 70° 51.5' W) to waters around Georges and Lovell Islands.

NOTE B

PRECAUTIONARY AREA

Traffic within the Precautionary Area may consist of vessels operating between Boston Harbor and one of the established traffic lanes. Mariners are advised to exercise extreme care in navigating within this area.

Recommended traffic lanes have been established for the approach to Boston Harbor. Use charts 13200 and 13267.

Aids to Navigation (ATONs)



ATONs

- Bouys – floating, anchored to bottom
- Beacons – fixed to land, lit or unlit
 - Lights – fixed to land and lit
 - Daybeacons – fixed to land and unlit

ATON Identification











Ways to identify bouys:

- Floating (bouys) or fixed to land (beacons)
- Color (red, green, yellow, etc.)
- Shape (cylinder, cone, tower, ball, etc.)
- Topmark (ball, cone)
- Light color and pattern
- Numbers or letters
- Sound (bell, gong, whistle, fog horn)
- Radar transponder (RACON)

ATON Usage

- Lateral marks – mark sides of a channel (red, green)
- Center channel markers (red/white striped)
- Danger marks (red/black or other)
- Cardinal indicators (indicate safe water in one direction)
- Warnings/restrictions (white/orange)
- Other special purposes (yellow)

Light Characteristics

Description	Characteristic	Chart Abbreviation
Alternating		Alt. R.W.G.
Fixed		F.
Flashing		Fl.
Group flashing		Gp Fl.(2)
Occulting		Occ.
Group occulting		Gp Occ(3)
Quick flashing		Qk.Fl.
Very quick flashing		V.Qk.Fl.
Isophase		Iso.
Morse		Mo.(letter)

Lateral Marks

“Red Right Returning”

Usually mark a channel. Can be bouys, lights or daybeacons. Keep red lateral marks to starboard (to the right) when “returning” to a smaller harbor from a larger body of water.

Green:

- Odd Numbers
- Square or Cylinder

Red:

- Even Numbers
- Triangle or Cone

Cans & Nuns

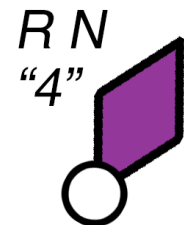
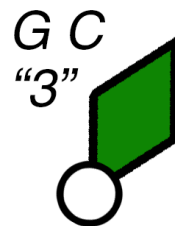
- Are never lighted.
- Never have sounds
- When used as lateral marks:

Cans:

- Green
- Odd number

Nuns:

- Red
- Even number

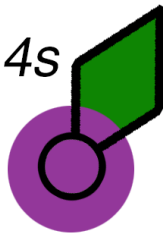


Tower Bouys

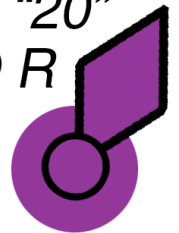
- May be lighted or have sounds.
- Light color usually matches bouy color



G "1"
Fl G 4s



R "20"
Q R

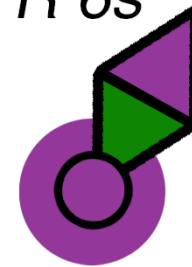


Preferred Channel Bouys

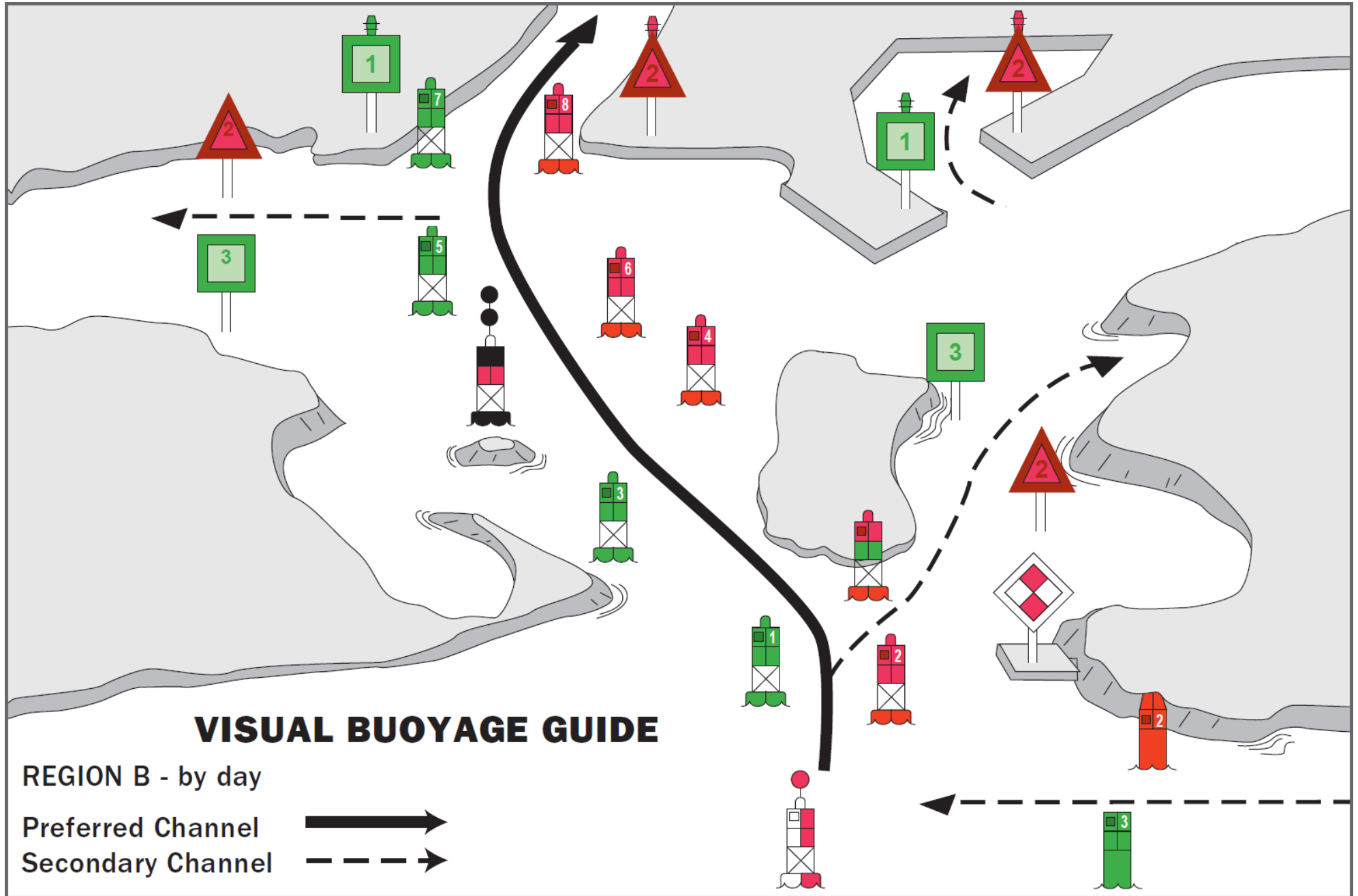
- Red/Green/Red or Green/Red/Green
- Placed at channel intersections
- Top color indicates preferred channel
- No numbers, may be lettered



RG "PR"
Fl (2+1) R 6s



Lateral System




Center Channel Bouys

- Red & white vertical stripes
- Ball topmark
- If lit, white morse-A light pattern (•—)
- Sometimes have whistles
- Sometimes have radar transponders

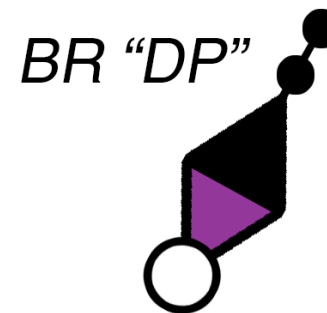


RW "M"
Mo (A)
WHIS
RACON (--)

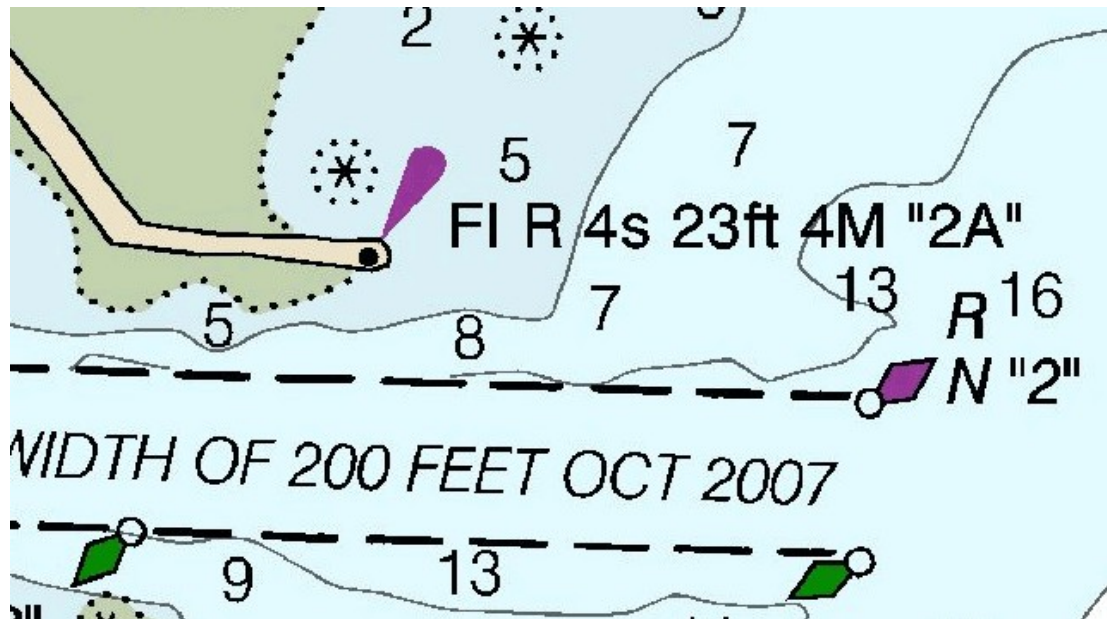


Danger Bouys

- Red & black
- Two black ball topmarks
- No numbers, may be lettered
- If lit, white (2) group flashing pattern

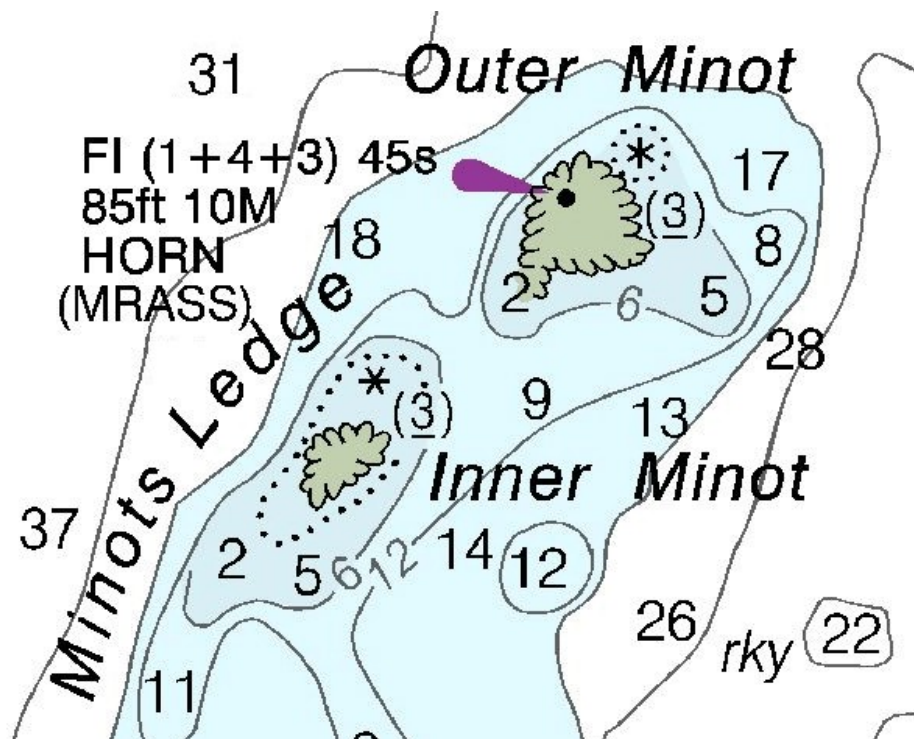


Lights



Scituate North Jetty Light 2A
Flashing Red 4s
23 feet above high water
4 miles nominal visibility

Lights



Minot Light

Group flashing (1+4+3) 45 sec.

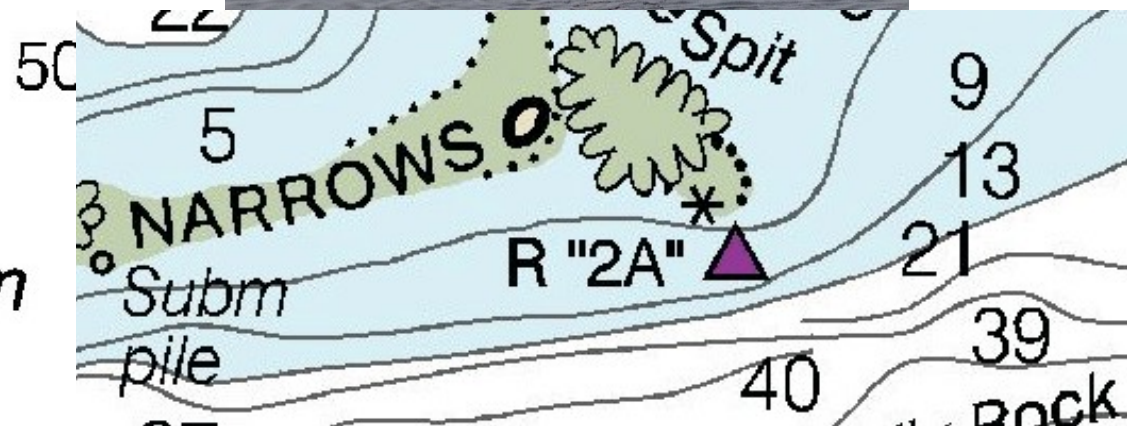
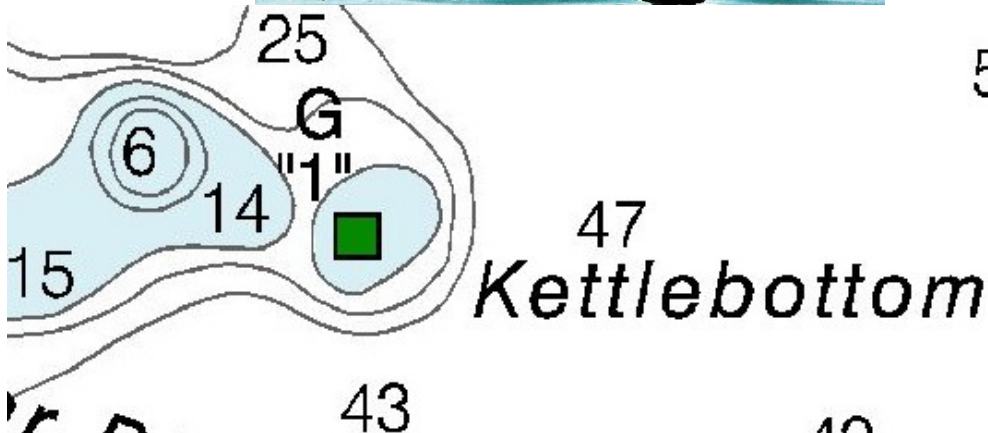
85 feet above high water

10 miles nominal visibility

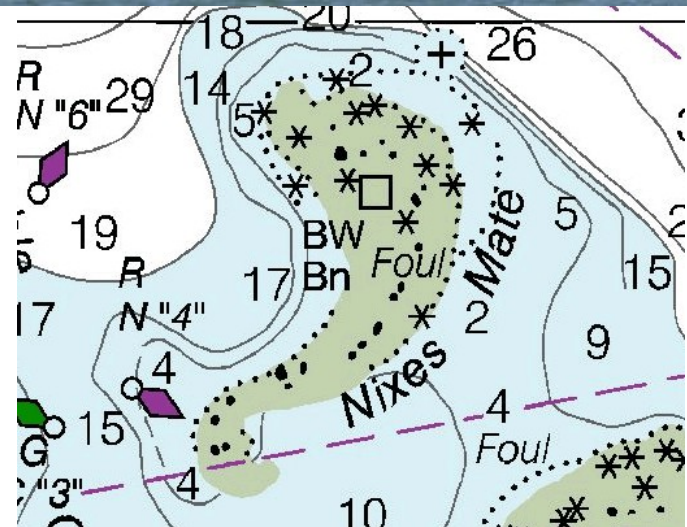
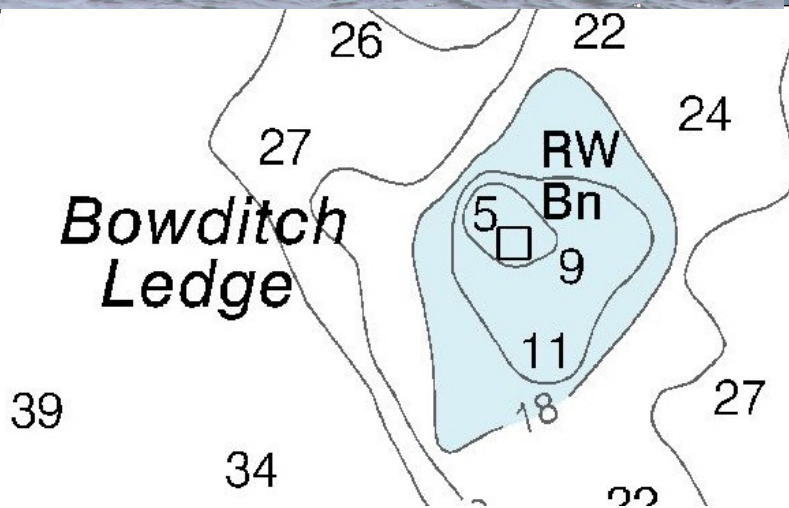
Fog Horn (MRASS)

Daybeacons

- No lights and fixed to land.



Daybeacons



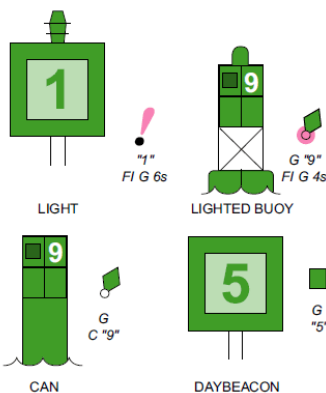
Do Not Tie Up to Navigational Aids



LATERAL SYSTEM AS SEEN ENTERING FROM SEAWARD

PORT SIDE ODD NUMBERED AIDS

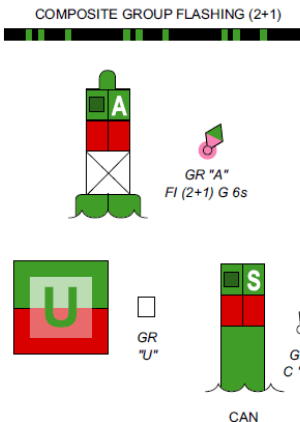
- GREEN LIGHT ONLY
- FLASHING (2)
- FLASHING
- OCCULTING
- QUICK FLASHING
- ISO



PREFERRED CHANNEL NO NUMBERS - MAY BE LETTERED

- PREFERRED CHANNEL TO STARBOARD
- TOPMOST BAND GREEN

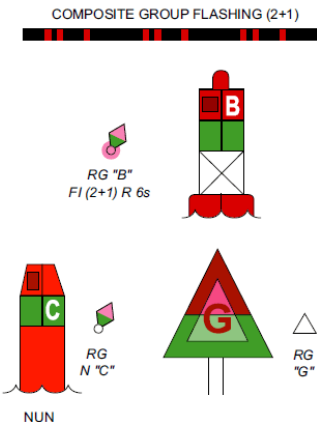
- GREEN LIGHT ONLY



PREFERRED CHANNEL NO NUMBERS - MAY BE LETTERED

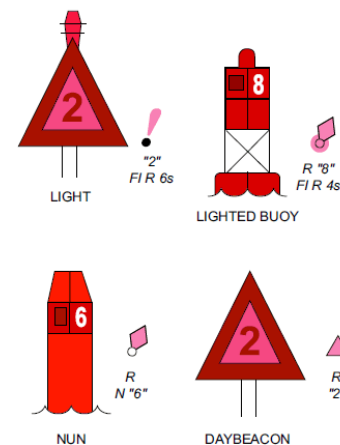
- PREFERRED CHANNEL TO PORT
- TOPMOST BAND RED

- RED LIGHT ONLY



STARBOARD SIDE EVEN NUMBERED AIDS

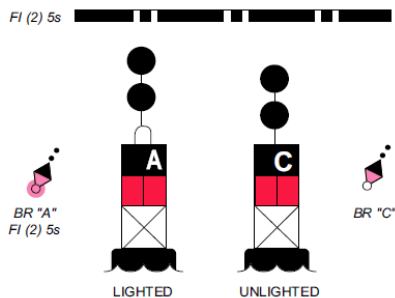
- RED LIGHT ONLY
- FLASHING (2)
- FLASHING
- OCCULTING
- QUICK FLASHING
- ISO



AIDS TO NAVIGATION HAVING NO LATERAL SIGNIFICANCE

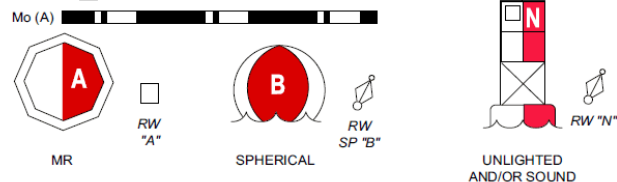
ISOLATED DANGER NO NUMBERS - MAY BE LETTERED

- WHITE LIGHT ONLY

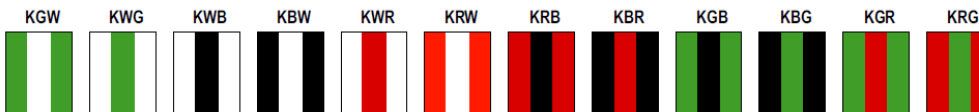


SAFE WATER NO NUMBERS - MAY BE LETTERED

- WHITE LIGHT ONLY
- MORSE CODE

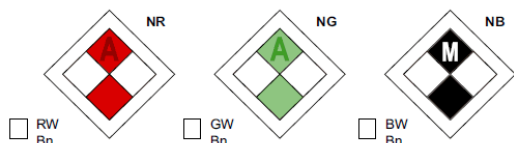


RANGE DAYBOARDS MAY BE LETTERED



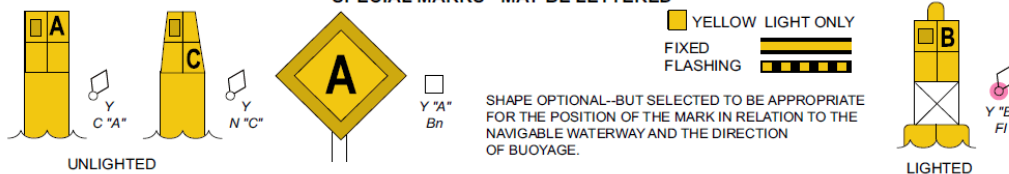
DAYBOARDS - MAY BE LETTERED

- WHITE LIGHT ONLY



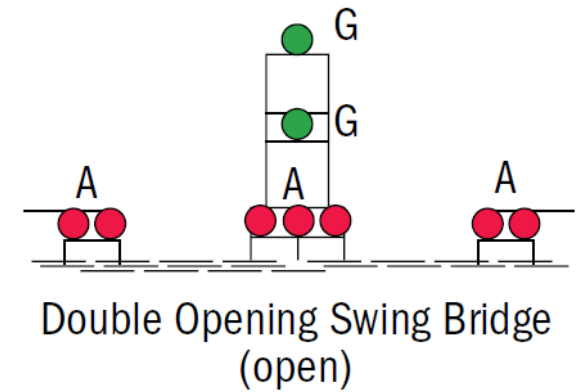
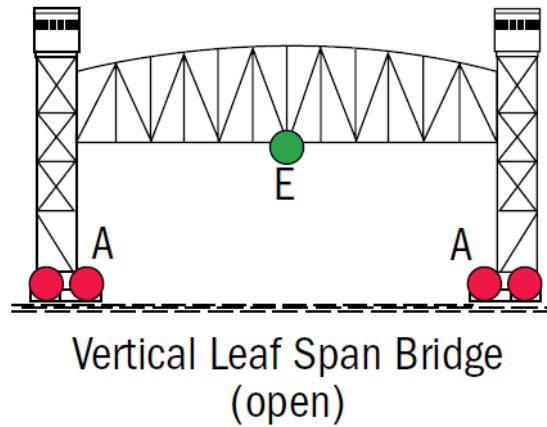
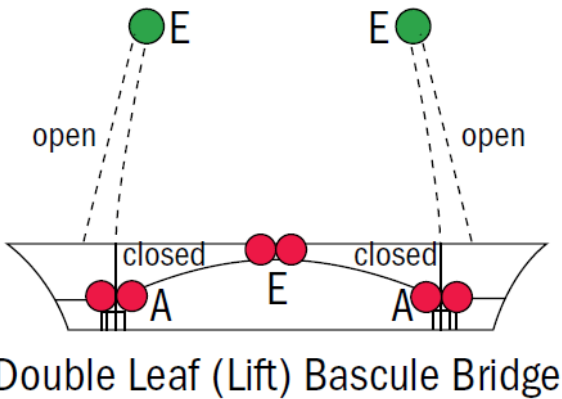
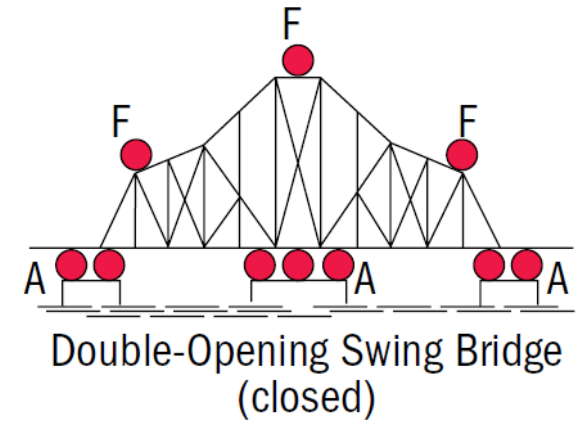
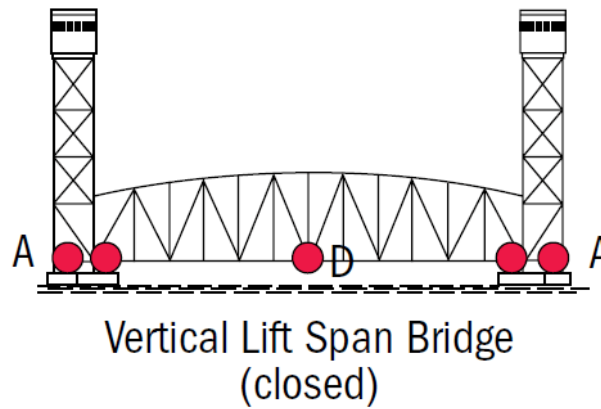
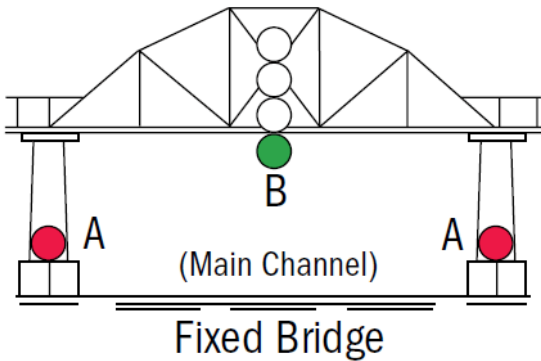
SPECIAL MARKS - MAY BE LETTERED

- YELLOW LIGHT ONLY
- FIXED
- FLASHING



SHAPE OPTIONAL—BUT SELECTED TO BE APPROPRIATE FOR THE POSITION OF THE MARK IN RELATION TO THE NAVIGABLE WATERWAY AND THE DIRECTION OF BUOYAGE.

Bridges



Light List

Full details on all official ATONs can be found in the “Light List” (navcen.uscg.gov) including:

- Official number
- Official name
- Latitude & longitude
- Light pattern details (if lit)
- Height (if on land)
- Nominal Range (if lit)
- Physical description (e.g. “White Conical Tower with Red Stripe”, or “Steel Tripod with Mast”)
- Additional Comments

The Magnetic Compass



The Ship's Compass

The compass is usually mounted on a pedestal called a “binnacle”. It is directly in front of the helm, so the helmsman can steer by it.

The compass contains a magnetized “card” floating in oil, weighted so it stays level, even if the ship is heeling. The heading is indicated by the numbers, written on the card, when they line up with the fixed “lubber's line”.



The Earth's Magnetic Field

The Earth's magnetic field is a three-dimensional vector field that changes in magnitude and direction over the surface of the Earth.

The magnetic field also varies slowly over time.

The magnetic poles (created by the Earth's magnetic field) do not line up with the geographic poles (defined by the rotation of the planet).

The Earth's Magnetic Field

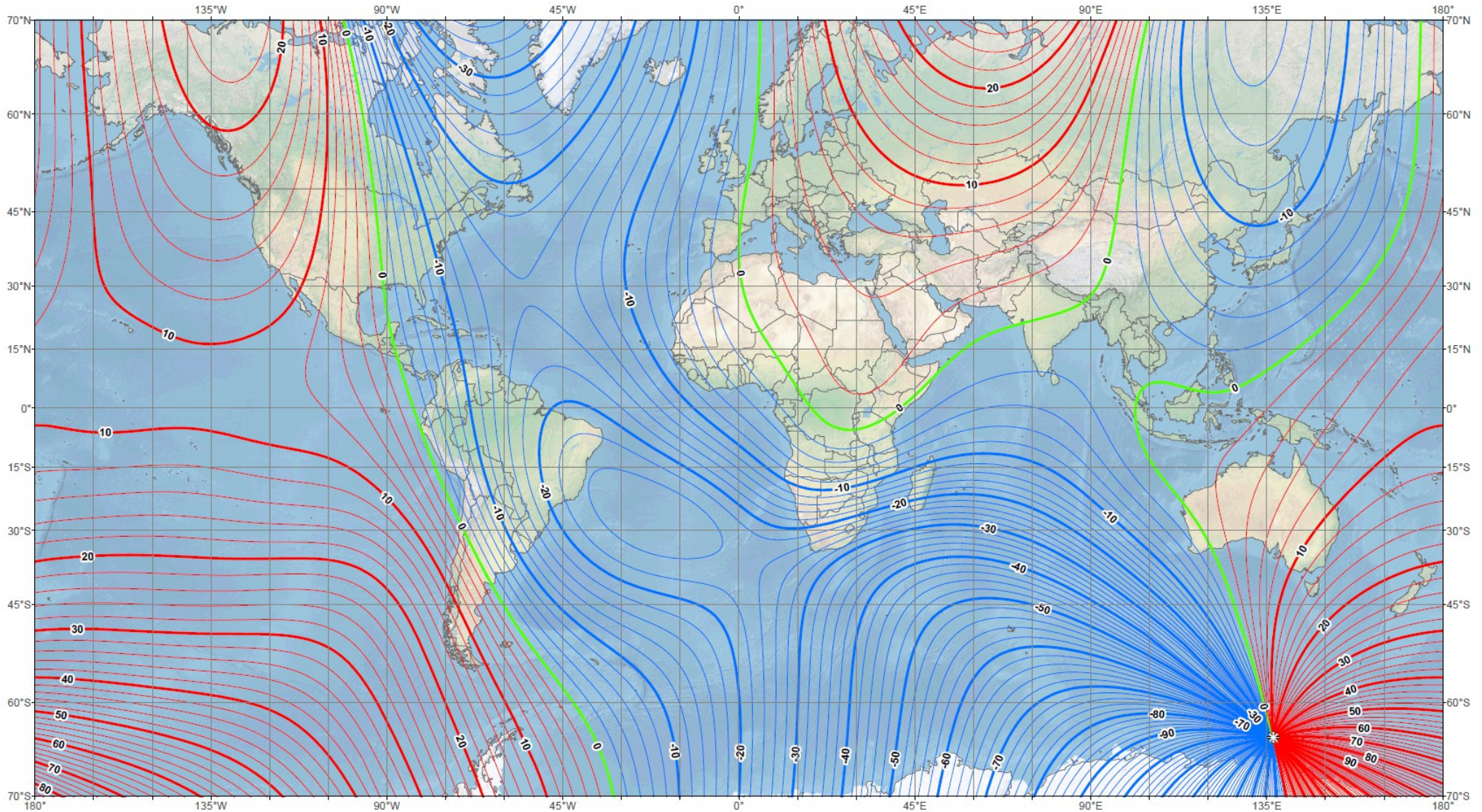
The geomagnetic field can be described at any given location on the surface of the Earth by two components.

- The vertical component (called the “dip”)
- The horizontal component (called the “declination” by land-lubbers, and called the “variation” by sailors).

Because of the dip, a compass needs to be kept level to give accurate readings.

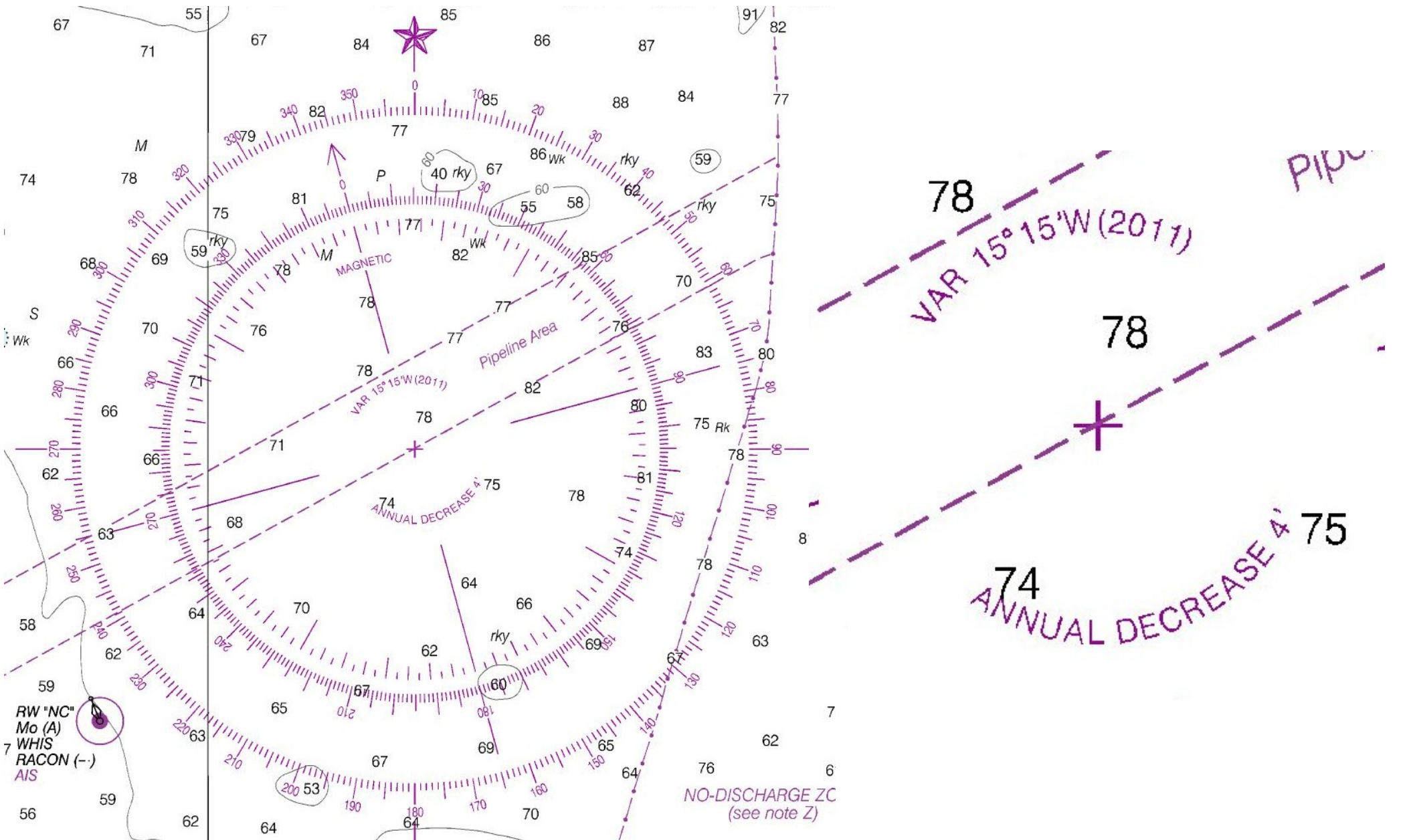
The Earth's Magnetic Field

US/UK World Magnetic Model - Epoch 2015.0
Main Field Declination (D)

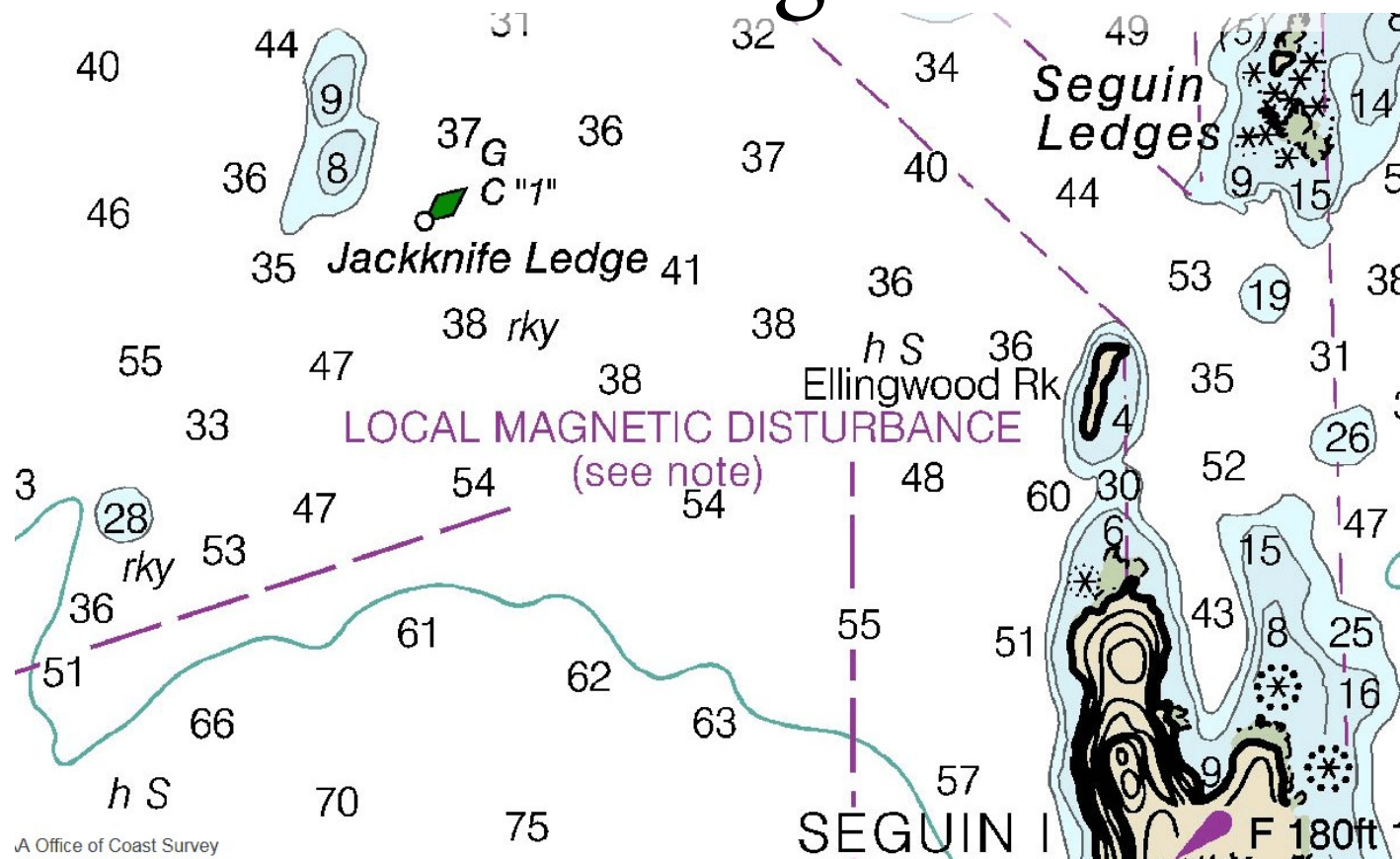


Compass Rose

Outside ring: True, Inside ring: Magnetic



The Earth's Magnetic Field



LOCAL MAGNETIC DISTURBANCE

Differences of as much as 8° from the normal variation have been observed in an area around Ellingwood Rock for approximately 1 nautical mile in all directions.

Magnetic Variation

Magnetic *variation* is the difference between a “true” direction and a “magnetic” direction (that which would be read from an ideal compass).

- Can be determined from compass rose on chart
- Can be calculated by a computer (GPS)
- Can be looked up in a variety of locations.

Bearings, courses and headings always need to be specified whether they are “true” or “magnetic”.

Magnetic Deviation

Magnetic *deviation* is the error in the compass reading caused by nearby magnetic field sources:

- Electric currents in nearby wires
- Nearby steel or other ferrous metals
- Nearby magnets (speakers, magnetized metal, etc).

Deviation is a function of the direction the compass is pointing. Each compass on each boat will have a slightly different deviation function.

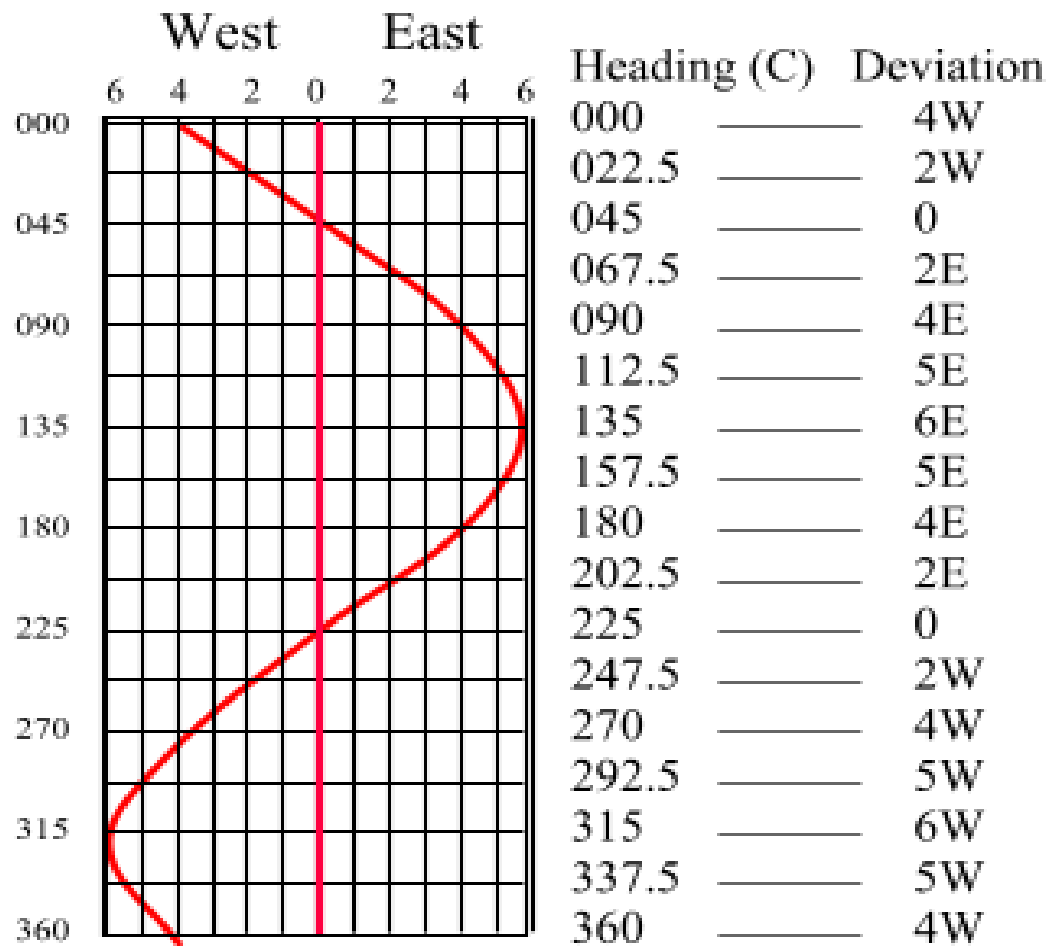
Magnetic Deviation

To determine deviation of a ship's compass:

- Point the boat in a known heading (!)
- Take a compass reading
- Correct for magnetic variation
- Write down the difference
- Repeat for several different headings
- Plot the results on a graph
- Create a table of deviations for each heading

Magnetic Deviation

A Deviation Table



Compass Heading Correction

Can	Compass
Dead	Deviation
Men	Magnetic
Vote	Variation
Twice?	True

(at Elections) (add East)

Compass Heading Correction

Can	195°	Compass
Dead	3°E	Deviation
Men	198°	Magnetic
Vote	15°W	Variation
Twice?	183°	True

(at Elections)

(add East)

Compass Heading De-correction

True	True
Virgins	Variation
Make	Magnetic
Dull	Deviation
Companions	Compass
(add Whiskey)	(add West)

Compass Heading De-correction

True	46°	True
Virgins	15°W	Variation
Make	61°	Magnetic
Dull	2°E	Deviation
Companions	59°	Compass

(add Whiskey)

(add West)



Online Resources:

- navcen.uscg.gov
- charts.noaa.gov
- ngdc.noaa.gov/geomag/WMM/DoDWMM.shtml