

Essentials of Navigation

Latitudes & Longitudes, GPS, and more...

For Race Officers and Mark Boat Operators

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ezTrap



v13

A unique MS Excel-based system that helps sailboat Race Officers plan uniform and accurate race courses anywhere in the world.

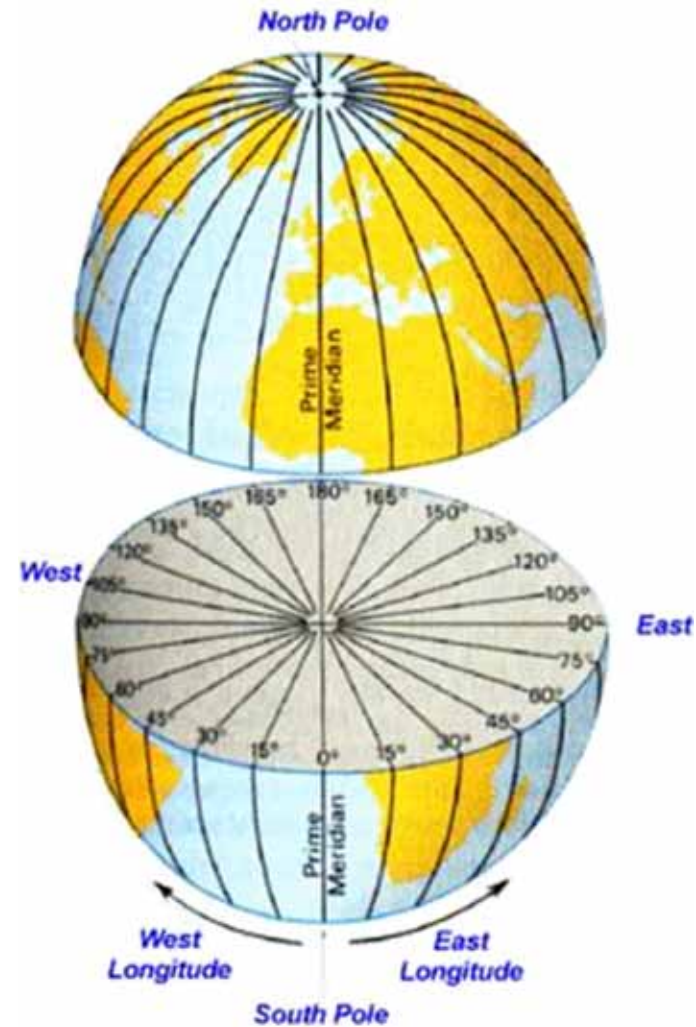
Topics

- Latitude & Longitude
 - Degrees, minutes and seconds
 - Location on the globe
- Mariner's Compass
 - Headings and Bearings
 - Magnetic Compass
 - Variation and Deviation
 - Chart Compass Rose
 - Converting True-Magnetic-Compass readings using Variation and Deviation
- Marine Charts
- GPS
 - How GPS Works
 - Using GPS to set Race Marks



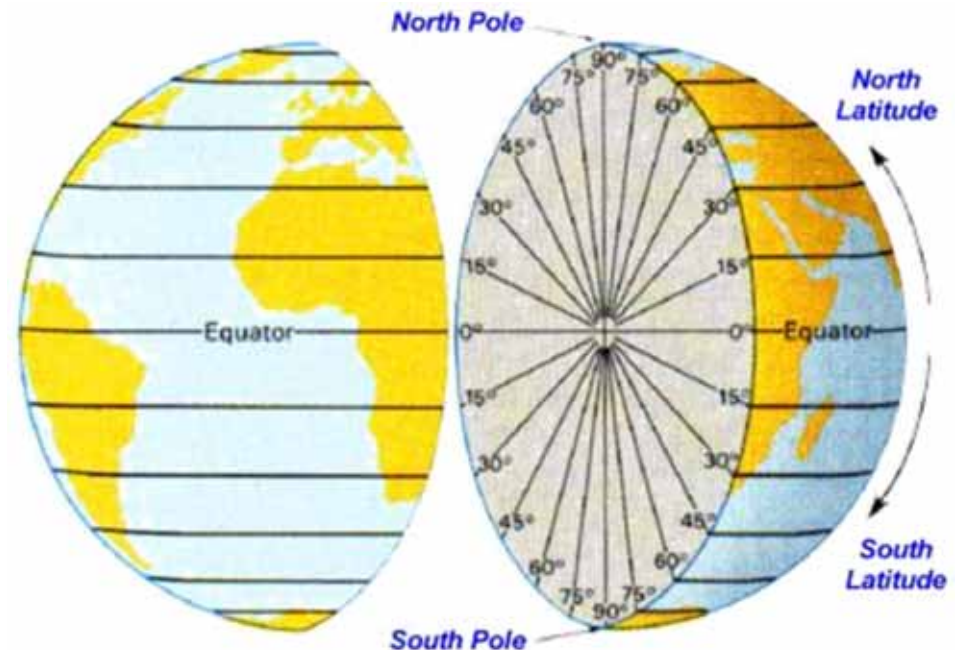
Great Circles, Meridians and Longitude

- Great circles
 - Line formed by intersection of plane thru center of sphere
 - Both halves of sphere are same size
- Meridians or Lines of Longitude
 - Great Circles that also include North & South Poles
 - Prime Meridian (0° Longitude) runs through Greenwich, UK - Royal Observatory
- A line of Longitude is measured in degrees, minutes and seconds (or in decimal minutes) from the Prime Meridian
 - $0-180^{\circ}$ East or West of Prime Meridian
 - Halifax, NS = about $63^{\circ} 35'$ Longitude (same line that runs just E of Bermuda, and between Argentina & Falkland Islands)
 - Kandahar about $65^{\circ} 42'$ E Longitude
 - Eastern islands of Fiji are near 180° W, Western islands near 180° E



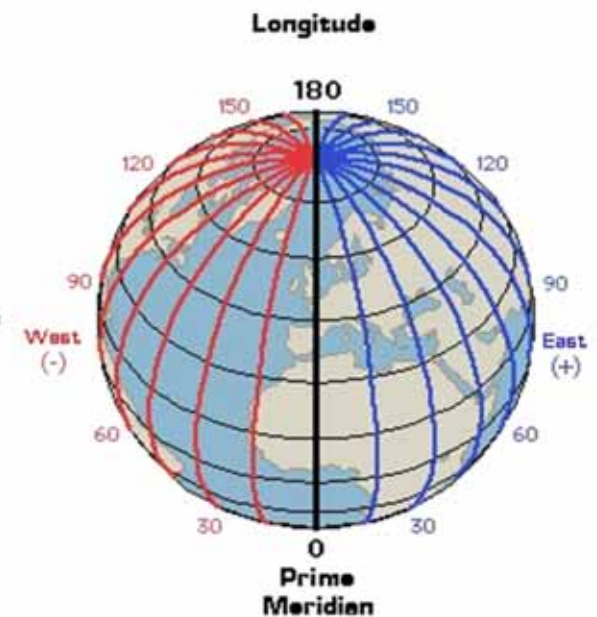
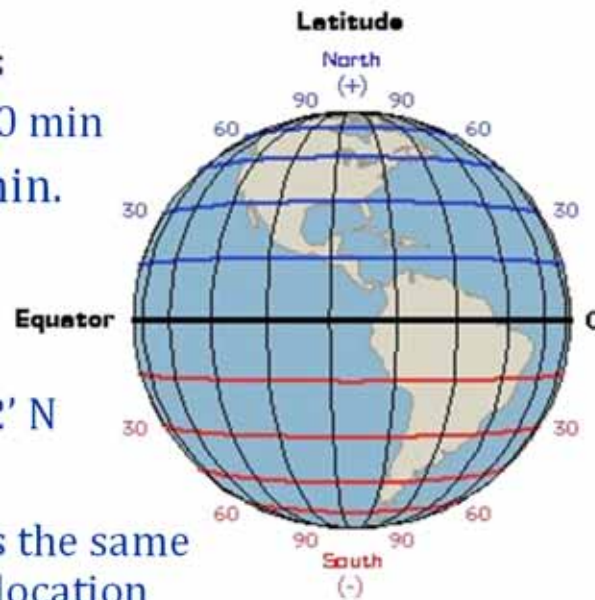
Parallels of Latitude

- Parallels of latitude
 - Small circles perpendicular to Equator
 - Equator is a GC, perpendicular to Earth's axis
 - Latitude is measured 0-90° North or South of Equator from the centre of the Earth
 - Halifax 44° 38' N
 - Christchurch, NZ 43° 32' S
- 1' Minute (arc) of Latitude = 1 Nautical Mile (nm)
 - 1 nm is about 15% longer than Statute Mile, = 6,076 Feet, = 1,852 M
 - 1 nm per hour = 1 knot (kt)
 - One unit of Latitude has the same length regardless of its location



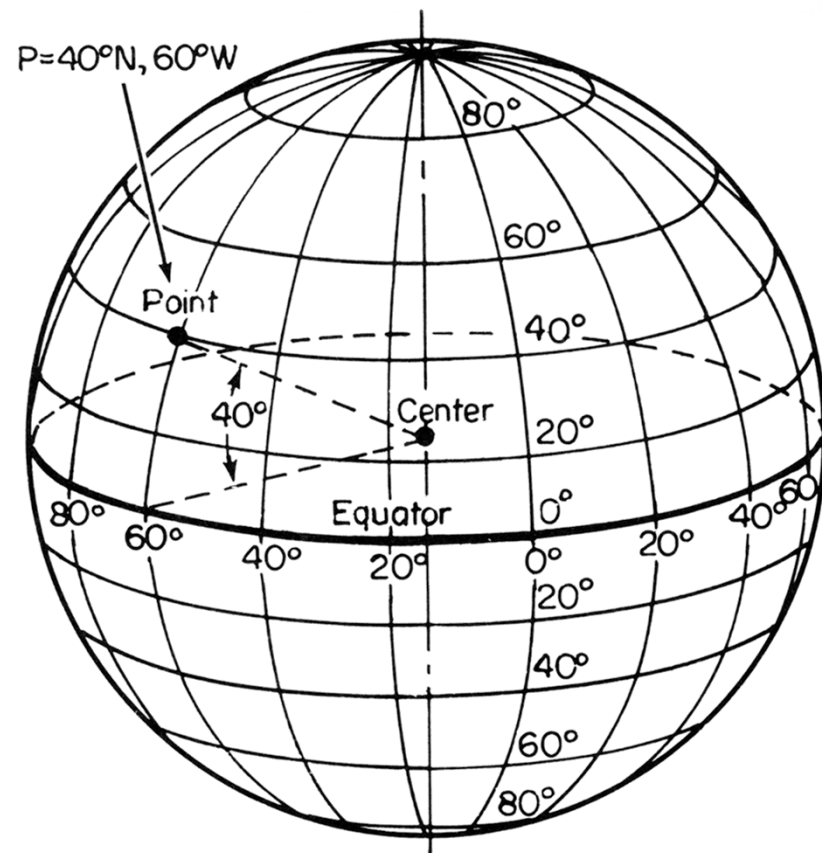
Degrees, Minutes and Seconds

- Angular measures
 - 1° degree = 60' minutes
 - 1' minute = 60" seconds
 - Similar to Time: 1 hr=60 min
- Decimals preferred for min.
 - Min. = Sec./60:
 - $15'' = 0.25'$
 - $30'' = 0.50'$
 - $44^\circ 38' 12'' \text{ N} = 44^\circ 38.2' \text{ N}$
- Measuring Distance
 - One unit of Latitude has the same length regardless of its location
 - The same unit of Longitude has a variable length that reduces as the location moves N or S of the Equator



Where are you?

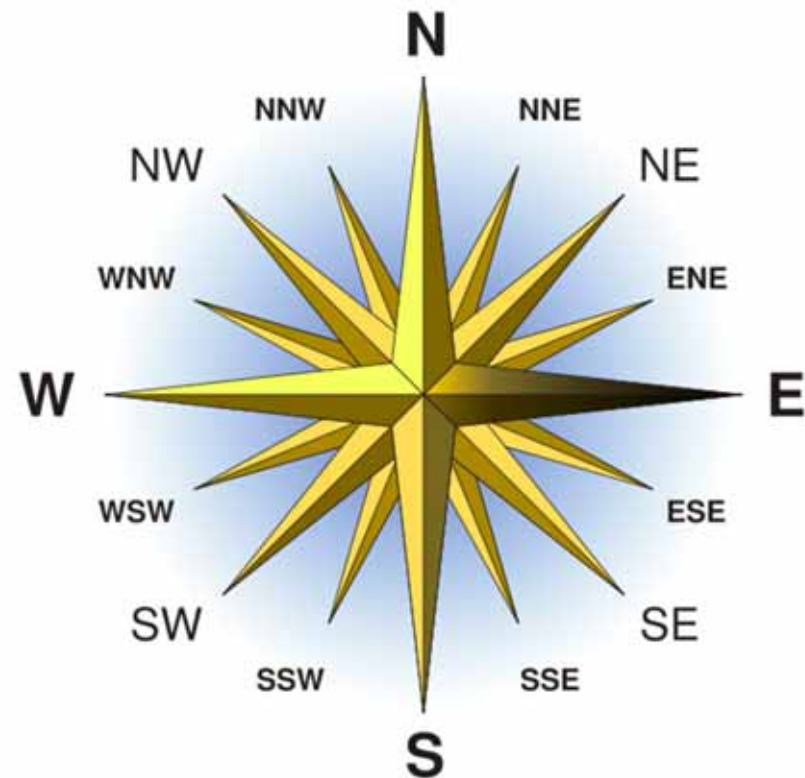
- Any point on Earth can be described by its Latitude and Longitude
- Latitude:
 - 0-90° N or S of equator
 - Marked on L & R sides of charts
 - 1' Latitude = 1 nm
- Longitude:
 - 0-180° W or E of Prime Meridian
 - Marked on Top & Bottom of charts
- Accuracy
 - $\pm 0.1'$ for chart work
 - GPS $\pm 0.001'$
 - Charts – decimal minutes, no seconds



**Always use the Latitude scales
(i.e. Left & Right side of charts)
to measure distances. 1' = 1nm**

Mariner's Compass

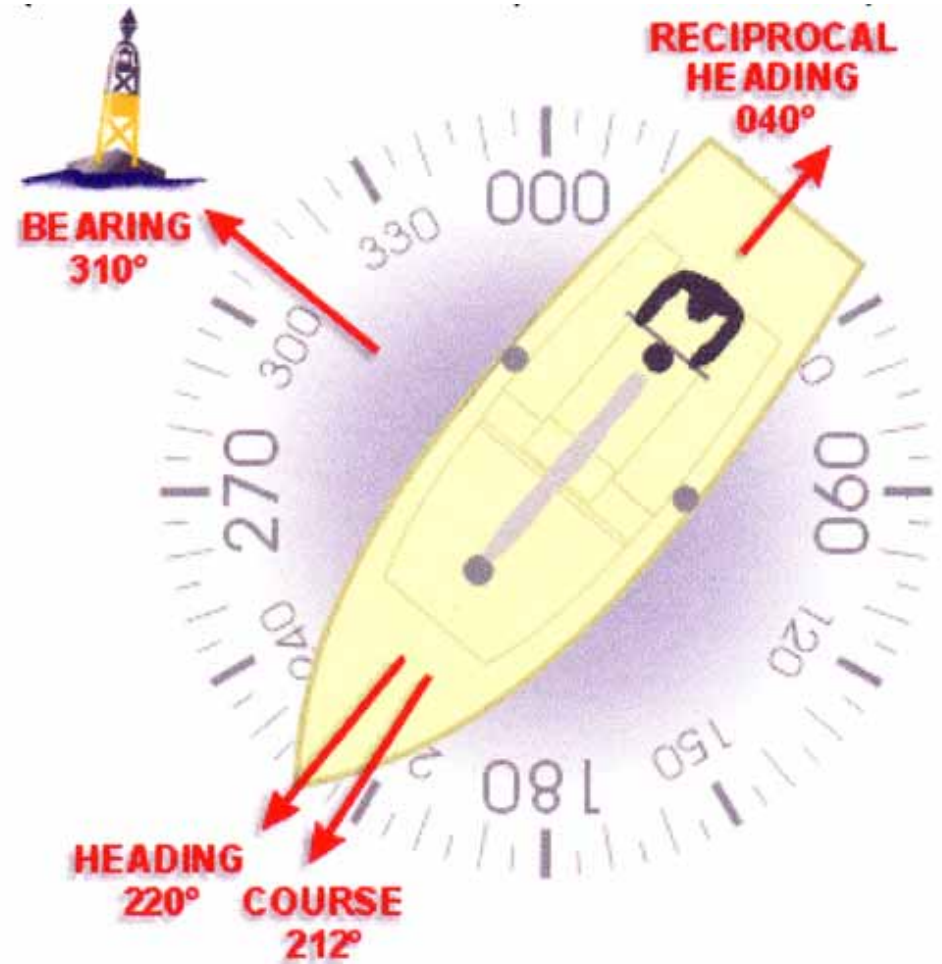
- Circular scale 000° - 359°, clockwise
 - No decimals used
 - Can be absolute or relative
 - E is 090°
 - 90° off starboard bow is relative
 - 3-digits used for absolute (015° not 15°)
- Some old references still used
 - Prior to WWII
 - North, NE, NNE, etc.
 - 000° =N, 090°=E, 180°=S, 270°=W
 - Today - do not say “steer NNE” (22.5°), rather 022° or 023°
- Directions usually taken from where you are, and absolute
 - Exception: Wind Direction is towards you (e.g. wind 225° = from the SW to you)
 - Exception: Relative Bearing (e.g. buoy 45° off port bow)



16-point Compass Rose

Headings and Bearings

- Heading: where the bow is pointing
- Course: the direction the boat is actually travelling (e.g. effects of leeway and/or current)
- Bearing: the direction of an object as determined by a compass
- Reciprocal (Heading, Bearing, Course, etc.): opposite direction (180° difference)



Magnetic Compass & Card

- Ship's Compass
 - Typically Binnacle or dash mounted
 - One moving part – card in transparent housing with damping fluid
 - Card aligns with Magnetic North – boat moves underneath
 - Built in magnets with adjustments to help alignment
 - Lubber's Line parallel to centerline of boat
 - Affected by metal and magnetic fields on-board (Deviation)
- Handheld Magnetic Compass
 - Card aligns with Magnetic North
 - No significant Deviation



True vs. Magnetic North

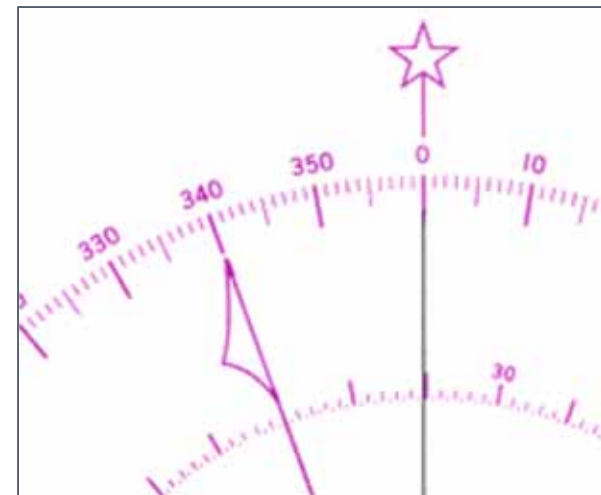
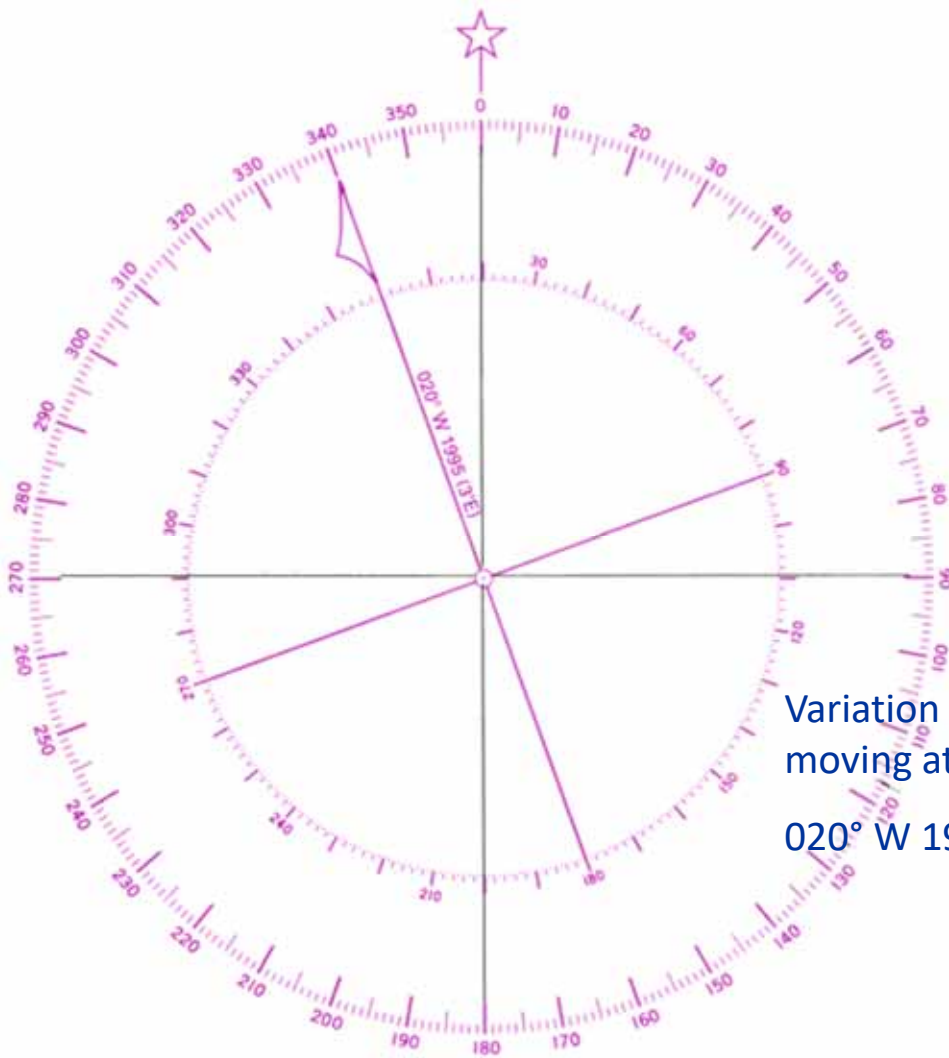
- Charts drawn relative to **True** North
 - North Pole 400+ miles from magnetic North Pole
- A **Magnetic** Compass points to Magnetic North
 - W. of Ellesmere Island , Canada about Lat. 83° N Long. 114° W
 - Moving to NW towards Siberia (about 25-miles per year)
- Difference is **Variation or Magnetic Declination**
 - Changes depending on your location:
 - 19°W at Halifax, NS, CA
 - 0° at Duluth, MN
 - 18°E at Vancouver, CA
 - 24°W at Cape Town, SA
 - 23°E at Wellington, NZ
 - Shown on charts – Compass Rose
- A magnetic **Compass** is also affected by localized iron and magnetism
 - Deviation : Measured in degrees E or W
 - Caused by Engine, tools, tanks, hardware, speakers, electrical power



- **Deviation** of installed ship's compass
 - Unique for each vessel
 - Adjustments can minimize to 5-10° max.
 - Varies by direction – Deviation Card
- Hand-held Compass (no deviation assumed)

<http://www.ngdc.noaa.gov/geomagmodels/IGRFWMM.jsp?defaultModel=WMM>

Compass Rose (On a Chart)

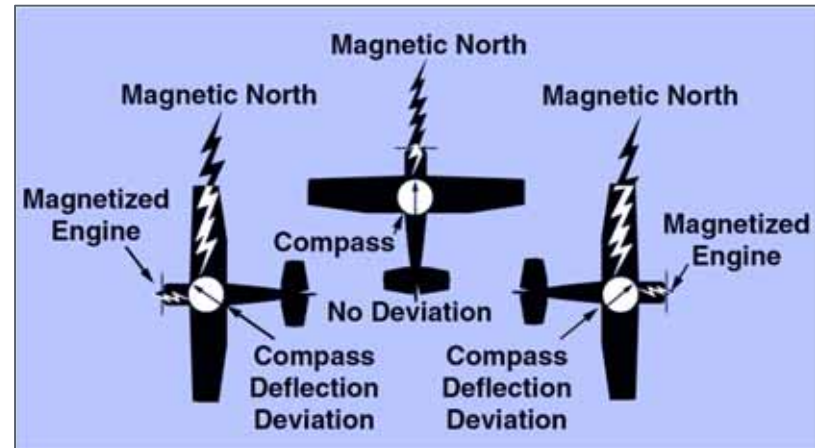


Variation shown as XXX° W or E, Year last measured moving at YY' E or W per year

020° W 1995 (3' E) is effectively 019° W in 2012

Converting True - Magnetic - Compass

- Why bother?
 - Is 15-25° difference material?
 - 20° over 5nm is 1.7nm!
- Variation Primarily a function of geography – relatively fixed
- Deviation varies by HDG and by specific boat ($\pm 5^\circ$ not unusual)
- When converting True to Magnetic, add **W Variation**
 - $270^\circ T + 20^\circ W = 290^\circ M$
- Magnetic to Compass, add **W Deviation**
 - $290^\circ M - 5^\circ E = 285^\circ C$
- TVMDC <--E + W-->
 - $100^\circ T + 20^\circ W = 120^\circ M + 5^\circ W = 125^\circ C$
- Mnemonics
 - True Virgins Make Dull Company At Weddings: TVMDC+W
 - Can Dead Men Vote Twice At Elections: CDMVT+E



TVMDC
← E + W →

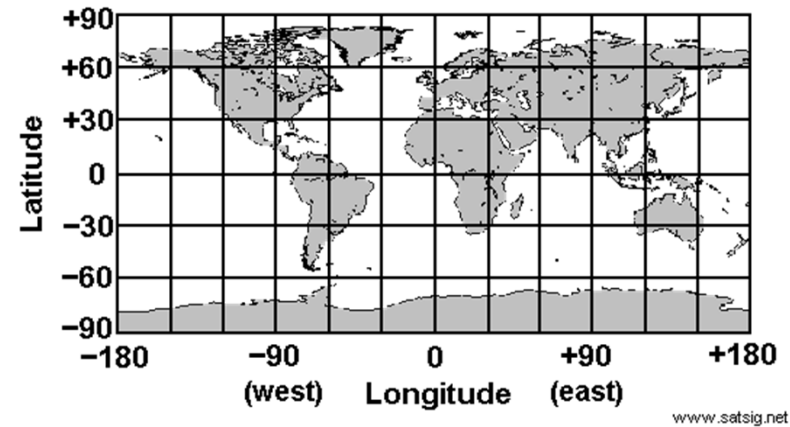


Other Factors

- Electronic Compasses (Fluxgate and GPS)
 - Deviation can be eliminated
 - Choice of Magnetic or True displays
 - Also good for creating or checking Deviation Card
- Leeway and Windage (powerboats)
 - Sideways movement, away from wind
 - Can be measured with coastal navigation chart work, trailing a line
 - Counteracted by changing Course to Steer (into the wind)
 - Function of wind direction, intensity and boat characteristics
- Current
 - Tidal currents will vary with cycle of tide (e.g. Ebb, Flow)
 - Other currents may be steady (e.g. rivers, Gulfstream)
 - Set (direction 000° -359°) and Drift (speed in kt)
 - Sometimes shown on Charts
 - Calculated by chart work

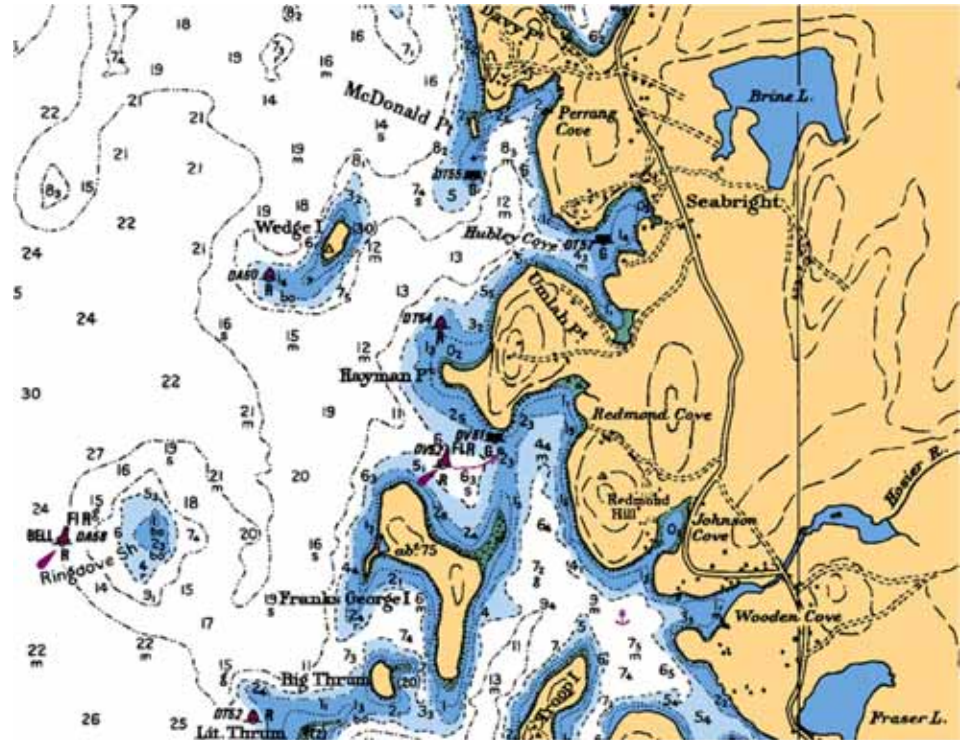
Marine (Mercator) Charts

- Little distortion, therefore true distances can be measured
 - 1' Latitude = 1 nautical mile (nm)
 - 1 nm per hour is 1 knot (kt)
 - Always use the Left or Right scales (Latitude) to measure distances
 - Linear scales OK for measurement in local area
- Chart scales vary from chart to chart
- Insets always have a different scale



Charts – Other Information

- Adjoining or inset Charts info.
- Compass Rose(s) show variation
- Warnings
- Reference tables
 - Feet-meters-Fathoms conversion
 - Tidal information
 - Distance scales
- Chart #1 – Symbols & Abbrev.
 - Natural & Cultural Features
 - Landmarks,
 - Seabed
 - Rocks, Wrecks, Obstructions
 - Commercial Routes
 - Security and special areas
 - Lights, Buoys, Fog Signals, Radar, and other Navigational Aids



Global Positioning by Satellite



- Satellites & Ground Stations (not discussed)
- Receivers



GPS accuracy typically 2-10m

Note: LORAN-C decommissioned in 2010

How GPS Works

- Receivers
 - Various formats and sizes – fixed, handheld, embedded
 - GPS receivers have been miniaturized to just a few integrated circuits
 - Receives and analyzes signals from satellites (12-20 possible)
 - Memory to record time, last position, setup, route information, etc. even when unit is powered off
 - GPS for PCs < \$100
- Transfer of data
 - NMEA 0183 or 2000
 - Serial, USB or Bluetooth





How GPS Works

- Receiver Signal Analysis
 - By signal matching, the receiver determines the distance from each a satellite
 - Uses some correction information transmitted by each satellite to refine this information – typically 4+ satellites to get accuracy within 10-15m
- Improving Accuracy – Differential GPS
 - Uses signal from one or more “near-by” ground station to correct positions
 - Canadian & US Coast Guard supported Differential GPS uses local ground stations
 - WAAS – Wide Area Augmentation System is an American system that calculates corrections and then transmits them from 2 geostationary satellites
 - WAAS coverage is accurate in US and Southern Canada, less accurate on other regions of satellite coverage
 - Differential GPS improves accuracy to within 2 meters
- The receiver uses the position determined, and user entered data about waypoints to generate navigation displays
- Course steered is the result of receiving a number of positions to define travel over ground, including the effects of current and leeway
 - Course may not match your ships compass - GPS does not measure deviation
- Speed determined using the position information collected and the GPS system clock

Using GPS to Set Race Marks

- Functional capabilities and user instructions will vary with GPS manufacturer and model
 - Ensure the GPS and VHF/Cell communications units have been properly and consistently set-up
 - Horizontal Datum
 - Measurement units (e.g. knots, nm or metres)
 - True or Magnetic directions, including offsets
- Familiarize yourself with basic operations including:
 - Entering way points (e.g. Mark & Pin locations)
 - Go To way point navigation
 - Position or location display including satellite acquisition
 - Moving between screen displays
 - Alarms (e.g. proximity)
 - Power on/off – manual and automatic
- Getting to the Mark Location
 - Obtain Mark Latitude & Longitude, Range and Reciprocal Bearing from RO – double check.
 - Options:
 - Enter as a new Way Point, then use Go To function.
 - RC Boat can be entered as a Way Point for checking
 - Sail the Latitude – navigate to the desired Latitude then turn and sail to the desired longitude keeping the latitude constant, or vice versa.
 - Double check the Reciprocal Bearing to the RC Boat with a compass and/or use a Go To function to see the distance and bearing (Reciprocal) to the RC Boat.
 - If visible, ask RC Boat for confirmation of Bearing to Mark
 - Make appropriate adjustments (e.g. upwind) for drift when dropping the anchor of the mark