Essentials of Navigation

Latitudes & Longitudes, GPS, and more…

For Race Officers and Mark Boat Operators

From Sailwave Race Management Resources

sailwave

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ezTrap

A unique MS Excel© based system that helps sailboat Race Officers plan and manage racecourses anywhere in the world.

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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

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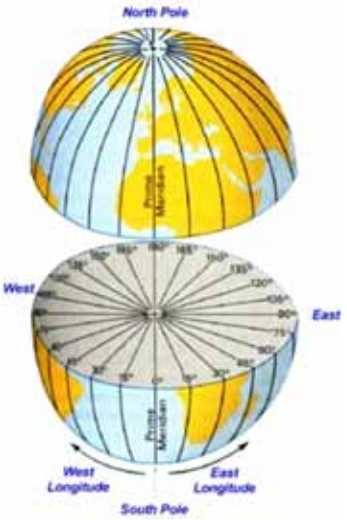
Great Circles, Meridians and Longitude

- Great circles
  - Line formed on the surface of the globe by the intersection of any plane thru center of the earth
  - 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° East or West of Prime Meridian
  - Halifax, NS = about 63° 35' Longitude (same line that runs just E of Bermuda, and between Argentina & Falkland Islands
  - Kandahar about 65° 42' E Longitude
  - Eastern islands of Fiji are near 180° W, Western islands near 180° E



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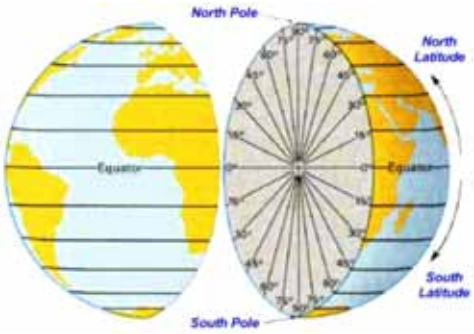
Parallels of Latitude

- Parallels of latitude
  - Small circles perpendicular to Equator
  - Equator is a great circle, perpendicular to Earth's axis
  - Latitude is measured 0-90° North or South of the 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



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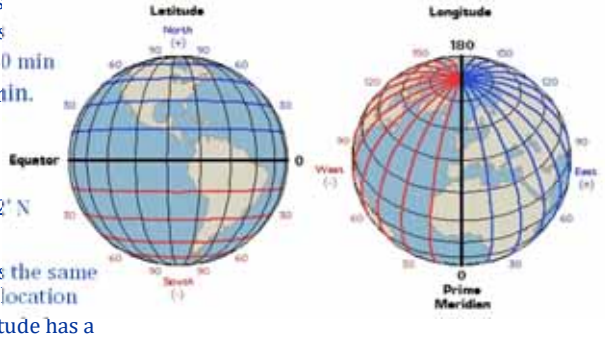
Degrees, Minutes and Seconds

- 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° 38' 12" N = 44° 38.2' 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



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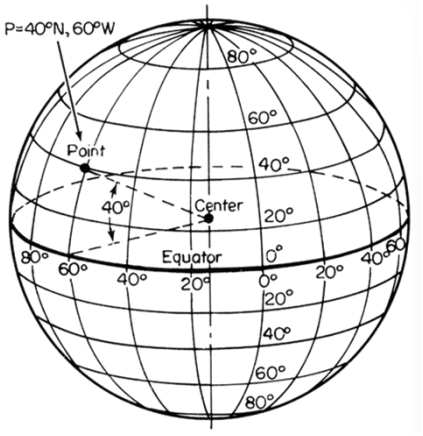
Where are you?

- 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
  - ±0.1' for chart work
  - GPS ±0.001'
  - Charts – decimal minutes, no seconds



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

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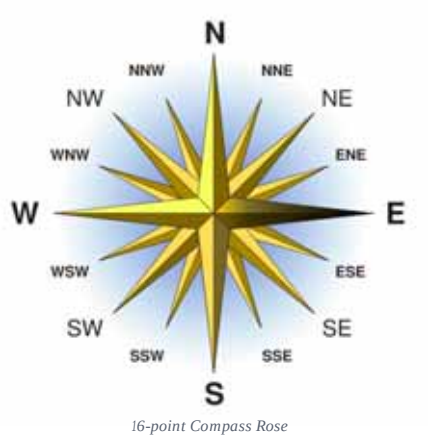
Mariner's Compass

- 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

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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)

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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

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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:
    - 18°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)

https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#declination

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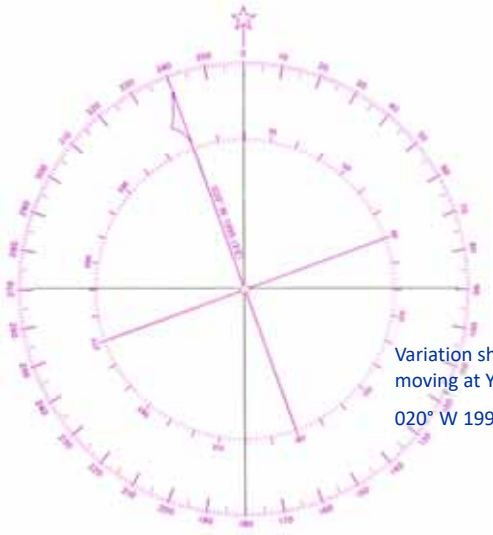
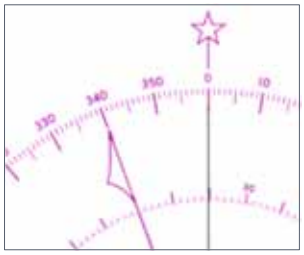
Compass Rose (On a Chart)





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

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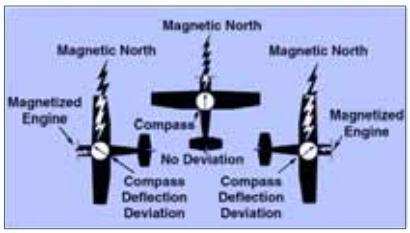
Converting True - Magnetic - Compass

- 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 (± 5 ° not unusual)
- When converting True to Magnetic, add W Variation
  - 270° T + 20° W = 290° M
- Magnetic to Compass, add W Deviation
  - 290° M - 5° E = 285° C
- TVMDC <--E + W-->
  - 100° T + 20° W = 120° M + 5° W = 125° C
- Mnemonics
  - True Virgins Make Dull Company At Weddings: TVMDC+W
  - Can Dead Men Vote Twice At Elections: CDMVT+E



TVMDC
← E + W →

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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

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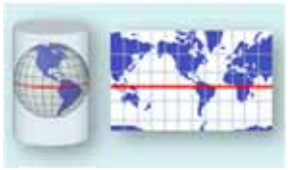
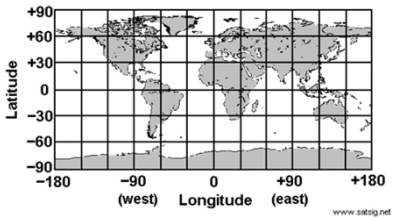
Marine (Mercator) Charts

- 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





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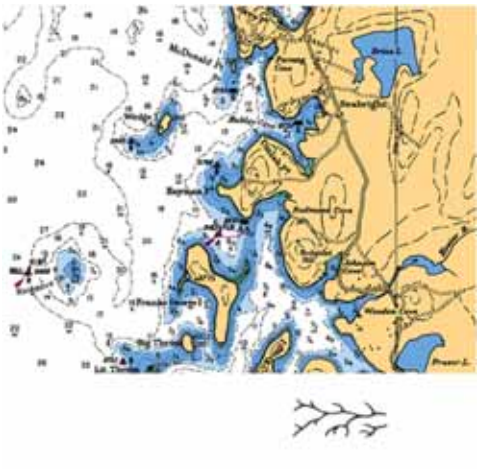
Charts – Other Information

- 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



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Global Positioning by Satellite

- Satellites & Ground Stations (not discussed)
- Receivers

GPS accuracy typically 2-10m

Note: LORAN-C decommissioned in 2010

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How GPS Works

- Receivers
  - Various formats and sizes – fixed, handheld, embedded (e.g. smartphone)
  - 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

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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

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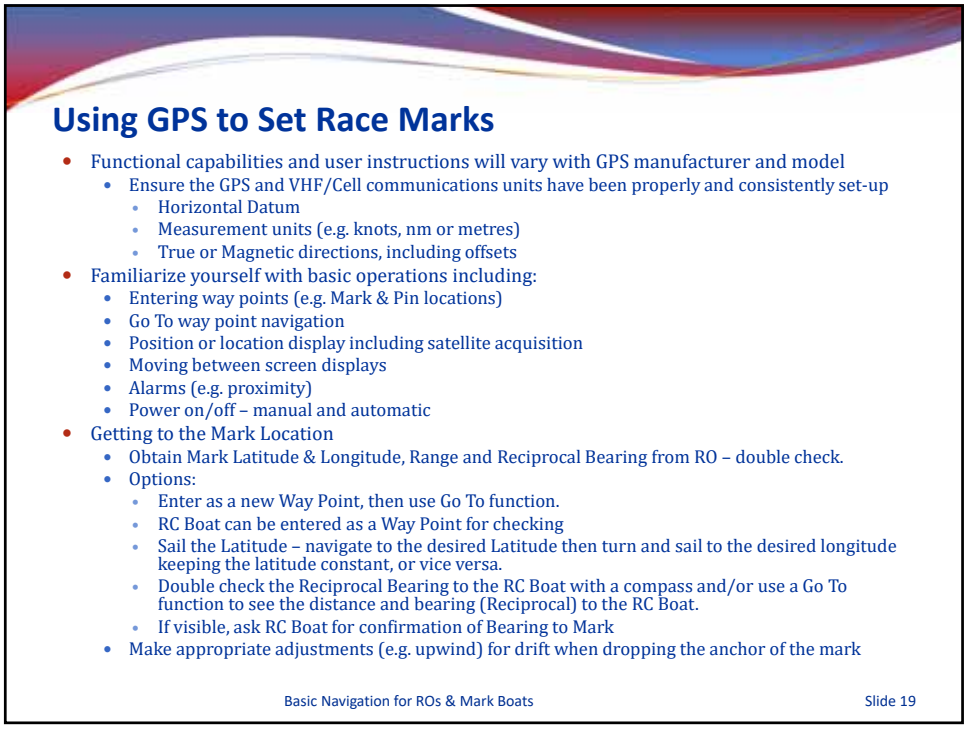

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