Celestial Navigation

Session II

Presented by Ralph Naranjo
Circles and spheres

- Great circles
- Longitude
- Latitude
- Equator
- Parallels
- Obliquity of ecliptic
Coordinates on the Celestial Sphere
The third sphere
Measuring altitude

90 - altitude = ZD
Solving the navigational triangle

- Spherical trig
- Sight reduction tables
- Calculator
- Computer program

\[
\cos a = \cos b \cos c + \sin b \sin c \cos A
\]

\[
\cos C = \frac{\cos c - \cos a \cos b}{\sin a \sin b}
\]
The evolution of the sextant
A sextant and its case
Momentary perch
Instrument history
Parallel Optics
Horizon mirror
Index arm mirror
Horizon and index filters
Precise gear to micrometer relationship
Read lower whole degree
Minute scale on drum
Match up the best aligned decimal mark on the micrometer scale
Index and horizon filters
Index mirror alignment
Index mirror not aligned correctly
Set index to 0°0’

- Measure index correction by first viewing the horizon with the above settings.
No index correction required
Index correction needed

- Turn micrometer dial to level horizon
- Record setting as IC factor
- On-it’s-off - - off-it’s-on
Additional alignment tests
Horizon and index mirrors are not parallel
In your hand or in the case
Rock sextant side-to-side

Hs in degrees minutes tenths
43° 24.3′
Touch lower limb to surface
Bring upper limb to surface
Rock the sextant
Time

- GMT set watch (check with WWV)
- Concept of mean time (sun v. clock)
- Equation of time
Local Apparent Noon
Light rays assumed parallel
Noon sight

- Meridian transit
- Longitude = GHA (western hemisphere)
- Estimate LAN
Noon Sight

Set sextant to the exact sextant angle recorded in #4 and not the time the sun reaches this point.

Shoot at approximate 3 min intervals.
<table>
<thead>
<tr>
<th>sight</th>
<th>Rising angle</th>
<th>Setting angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>21:13:52</td>
<td>XXXX</td>
</tr>
<tr>
<td>4</td>
<td>21:40:15</td>
<td>21:46:45</td>
</tr>
<tr>
<td></td>
<td>YYYY</td>
<td>YYYY</td>
</tr>
<tr>
<td>3</td>
<td>21:36:45</td>
<td>21:50:15</td>
</tr>
<tr>
<td></td>
<td>vvvv</td>
<td>vvvv</td>
</tr>
<tr>
<td>2</td>
<td>21:33:12</td>
<td>21:53:45</td>
</tr>
<tr>
<td></td>
<td>wwwww</td>
<td>wwwww</td>
</tr>
<tr>
<td>1</td>
<td>21:30:10</td>
<td>21:56:49</td>
</tr>
<tr>
<td></td>
<td>uuuu</td>
<td>uuuu</td>
</tr>
</tbody>
</table>

- 06:30
- 13:30
- 20:33
- 26:39
- 21:43:30
- 21:43:40
- 21:43:28
- 21:43:29
Example: The Longitude Calculation  
**Longitude: 2 June**

<table>
<thead>
<tr>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 h 43 m 30 s</td>
<td>GMT of local noon (from observation above)</td>
</tr>
<tr>
<td>- 12 h 00 m 00 s</td>
<td>Greenwich noon</td>
</tr>
<tr>
<td>09 h 43 m</td>
<td>1 hr clock - 15° of longitude</td>
</tr>
<tr>
<td>×</td>
<td>583.33                      Minutes of arc (nautical miles) from Greenwich</td>
</tr>
<tr>
<td>×</td>
<td>15                          Minutes/degree conversion</td>
</tr>
<tr>
<td>8752.5 m</td>
<td>145° 52′.5 W                Longitude position of mean sun</td>
</tr>
<tr>
<td>÷ 60</td>
<td>33′.0 W                     Equation of time for 2 June (from student tables)</td>
</tr>
<tr>
<td></td>
<td>146° 25′.5 W                Longitude of observer</td>
</tr>
</tbody>
</table>

1 min clock = 15′ of longitude
Example: The Latitude Calculation  

**Latitude: 2 June**

**Step One:** Finding corrected altitude of the sun.

<table>
<thead>
<tr>
<th>hs</th>
<th>84° 56’</th>
<th>Lower limb observation (your sextant reading at local noon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- IC</td>
<td>5’</td>
<td>Index correction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>84° 51’</td>
<td></td>
</tr>
<tr>
<td>- DIP</td>
<td>3’</td>
<td>Height of eye correction (see Fig. 8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>84° 48’</td>
<td></td>
</tr>
<tr>
<td>+ Ω</td>
<td>16’</td>
<td>Semi-diameter correction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho</td>
<td>85° 04’</td>
<td>Corrected altitude</td>
</tr>
</tbody>
</table>

**Step Two:** Applying the above formula for latitude

<table>
<thead>
<tr>
<th>89° 60’</th>
<th>Altitude of the sun at G.P. (89° 60’ = 90°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Ho</td>
<td>85° 04’ Corrected altitude of the sun (from “Step One” above)</td>
</tr>
<tr>
<td></td>
<td>4° 56’ Distance from the sun’s G.P.</td>
</tr>
<tr>
<td>+</td>
<td>22° 08’ N Declination of the sun, north of the equator on June 2 (from student tables)</td>
</tr>
<tr>
<td></td>
<td>27° 04’ N Latitude of observer</td>
</tr>
<tr>
<td>Item</td>
<td>General Data</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
</tr>
<tr>
<td>1.</td>
<td>Name of Body</td>
</tr>
<tr>
<td>2.</td>
<td>Limb (Upper/Lower)</td>
</tr>
<tr>
<td>3.</td>
<td>Date (G)</td>
</tr>
<tr>
<td>4.</td>
<td>Watch Time (G)</td>
</tr>
<tr>
<td>5.</td>
<td>Watch Error (if slow – if fast)</td>
</tr>
<tr>
<td>6.</td>
<td>GMT (six digits)</td>
</tr>
<tr>
<td>7.</td>
<td>DR Latitude (N/S)</td>
</tr>
<tr>
<td>8.</td>
<td>DR Longitude (E/W)</td>
</tr>
</tbody>
</table>

**Sextant Corrections**

---general

<table>
<thead>
<tr>
<th>Item</th>
<th>Sextant Reading (Hs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>instrument Corr. (+ or -)</td>
</tr>
<tr>
<td>10.</td>
<td>index Correction (+ or -)</td>
</tr>
<tr>
<td>11.</td>
<td>Dip Correction for 10 feet -</td>
</tr>
<tr>
<td>12.</td>
<td>Total (Items 9-12) is Apparent Altitude (Ha)</td>
</tr>
</tbody>
</table>
from inside front
back covers of
Almanac
14. Altitude Cor-
rection (+ or −)
15. Venus, Mars
only, add't correction (+ or −)
for daily page HP: (+)
17. Moon only, if
upper limb −30°
18. Non-Standard
conditions only,
add'l Corr.
19. Total (Items
13-18) is Observed
Altitude (Ho)

GHA—from Nautical Almanac

DAILY PAGES
20. GHA of body,
whole hours
• "v" value, planets
moon, + unless
shown otherwise

YELLOW PAGES
21. Increments, (+) 
minutes and secs.,
from sun/planets or
moon column.

22. Moon, planets,
"v" correction for "v" 
value above, use
same sign

23. Total GHA
(items 20-21 & 22)
• if over 360°
subtract 360°
Declination—From Nautical Almanac

DAILY PAGES
24. Declination, whole hour, (N/S)

• "d" value, (+ if Dec. increasing, - if Dec. decreasing)

YELLOW PAGES
25. "d" correction for "d" value above, use same sign

26. Total Declination (items 24-25) (N/S)
Assumed latitude
Assumed longitude

- DR 42° 18′N - 71° 36′W
- GHA 131° 29.1′
- Dec 22° 19.3′N

- aL 42°N  aλ 71° 29.1′W
- LHA 60°
Sight reduction table HO 249

- Dec Inc  +or-d
- Hc (Tab Alt)
- Dec corr’n
- Hc (Comp Alt)
- Ho (Obs Alt)
- Intercept
- Z to ZN
<table>
<thead>
<tr>
<th>LAT 50°</th>
<th>LAT 50°</th>
<th>LAT 50°</th>
</tr>
</thead>
<tbody>
<tr>
<td>27°</td>
<td>28°</td>
<td>29°</td>
</tr>
<tr>
<td>90°</td>
<td>60°</td>
<td>180°</td>
</tr>
<tr>
<td>90°</td>
<td>60°</td>
<td>178°</td>
</tr>
<tr>
<td>87°</td>
<td>60°</td>
<td>175°</td>
</tr>
<tr>
<td>83°</td>
<td>60°</td>
<td>173°</td>
</tr>
<tr>
<td>80°</td>
<td>59°</td>
<td>171°</td>
</tr>
<tr>
<td>81°</td>
<td>59°</td>
<td>169°</td>
</tr>
<tr>
<td>83°</td>
<td>59°</td>
<td>167°</td>
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<tr>
<td>83°</td>
<td>59°</td>
<td>164°</td>
</tr>
<tr>
<td>82°</td>
<td>58°</td>
<td>162°</td>
</tr>
<tr>
<td>80°</td>
<td>58°</td>
<td>160°</td>
</tr>
</tbody>
</table>
Exit table with

- Zn azimuth (true bearing to body)
- Intercept (offset distance of the LOP)
- DR
- AP
Plot directly on a chart
Advancing a line of position
tool v. instrument rule