DOCUMENT
GSM-G-CPL.026

DOCUMENT TITLE

NAVIGATION 1

CHAPTER 2 – THE EARTH AND POSITION

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CONTENTS

THE EARTH AND POSITION

2.1 The Form of the Earth

2.1.1 Introduction

Early ideas of the figure of the earth resulted in descriptions of the earth as an oyster (The Babylonians before 3000 B.C.), a rectangular box, a circular disk, a cylindrical column, a spherical ball, and a very round pear (Columbus in the last years of his life).

When Columbus sailed for India in the early 1490's, many people believed the ship would sail "over the edge" of the earth.

Today, our knowledge of the world has increased through travel, exploration and scientific discovery.

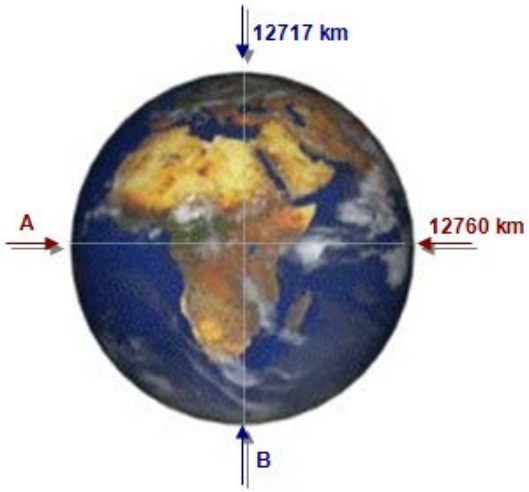
Navigation involves the movement over the surface of the Earth, whether on land, sea or in the air.

For this reason it is necessary to examine certain characteristics of the earth, and the effect this has on navigation.

2.1.2 Shape of the Earth

With reference to the form or shape of the earth, it can be said that it is neither a true circle nor a perfect sphere. The earth is slightly flattened at the top and bottom and bulges at the sides.

Thus, the shape of the earth can be described as an **ellipsoid** or **oblate spheroid** and the flattening of the earth at the top and bottom is known as **compression**.



2.2 Navigation Reference Datums

2.2.1 Introduction

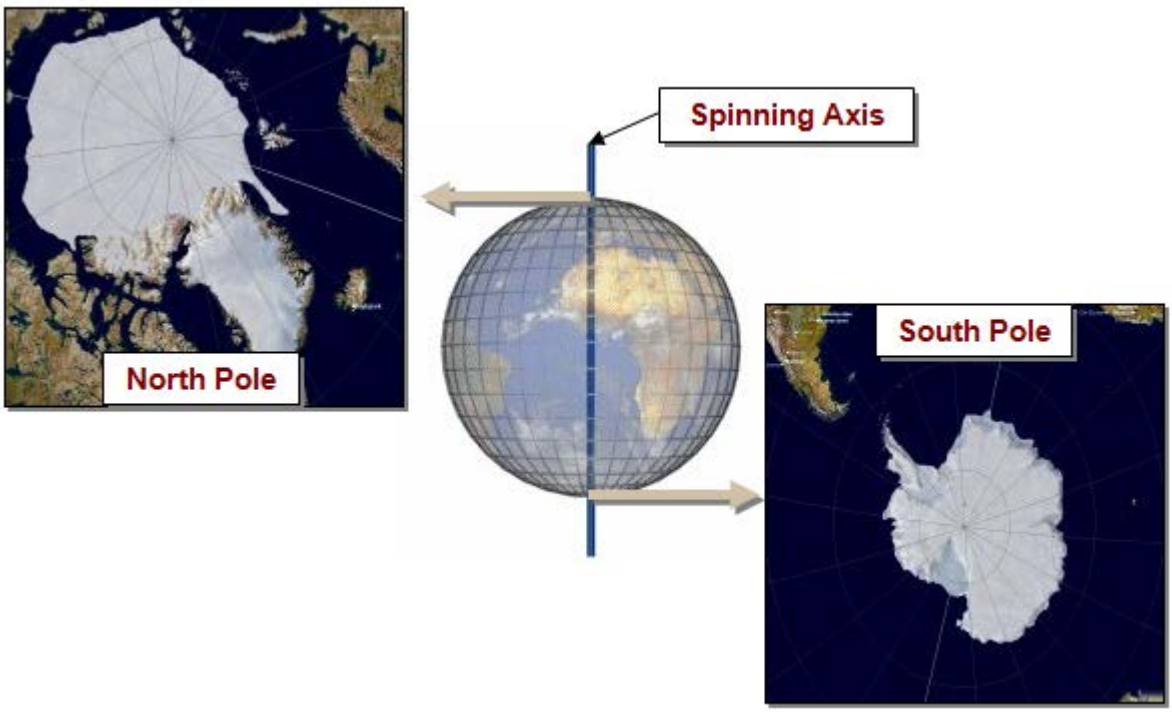
In order to establish a reference system for navigation purposes, it is necessary to adopt a convention defining the co-ordinates for direction finding and location fixing on the earth.

These are established as follows:

- The poles
- The Equator
- Cardinal points
- Longitudes
- Latitudes
- Great circles and rhumb lines.

2.2.2 The Poles

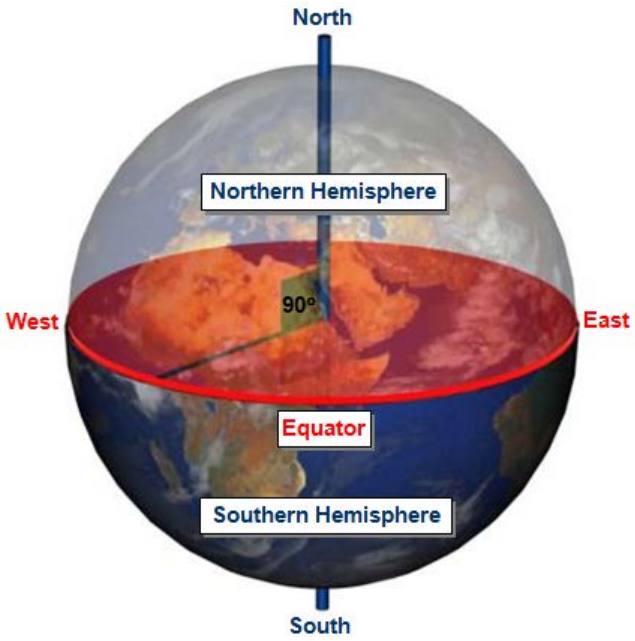
The earth turns about its spinning axis. The points were the earths spinning axis and surface meets is called the poles. The earth rotates anti-clockwise when viewed from above the North Pole.



The two poles locate the extreme northern and southern points on the earth, defining the directions, north and south. If you face in the direction of rotation, the North Pole will be on your left and the South Pole on your right.

2.2.3 The Equator

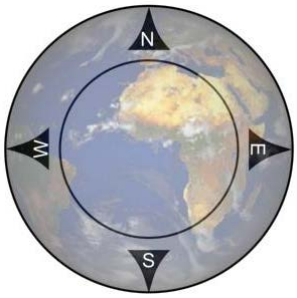
The Equator is a circle with its plane perpendicular to the earth's rotational axis.



All points on the equator are equidistant from the poles and divide the earth into equal halves known as the Northern and Southern Hemispheres.

2.2.4 Cardinal Points

In order to establish a reference system for navigational purposes, it is necessary to adopt a convention defining the co-ordinates for direction on the earth.



The direction of rotation is defined as east.

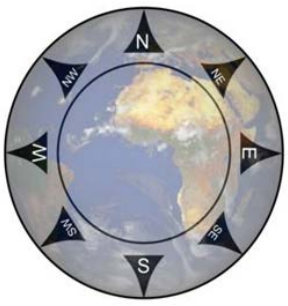
The rotational axis of the earth is the vertical division. Facing east, you will find north on your left.

The equator is a circle with its plane perpendicular to the earth's rotational axis, and defines the directions east and west.

These four points are known as the cardinal points and they are 90° apart.

Further divisions between the cardinal points are as follows:

- North east
- South east
- South west
- North west.



These points are 45° removed from the cardinal points.

The 45° segments are further sub-divided as follows:

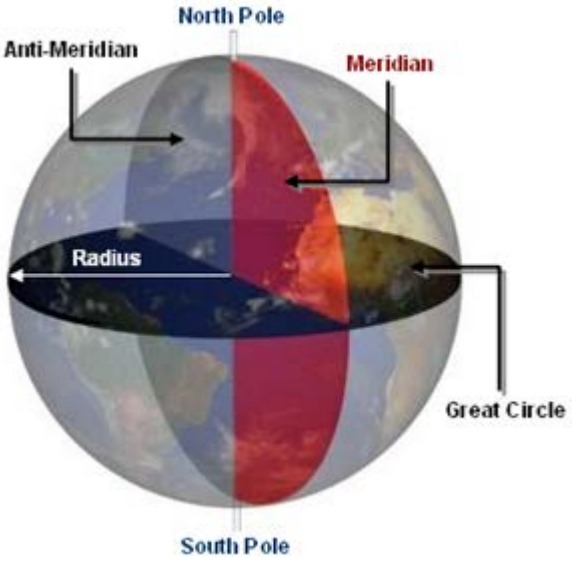
- North north-east
- East north-east
- East south-east
- South south-east
- South south-west
- West south-west
- West north-west
- North north-west.

Taking all points into consideration, a compass point is available every 22.5°.

As can be seen from the images above, every compass point has an angular value and it is these values that are generally used in aviation terms.

2.2.5 Meridians

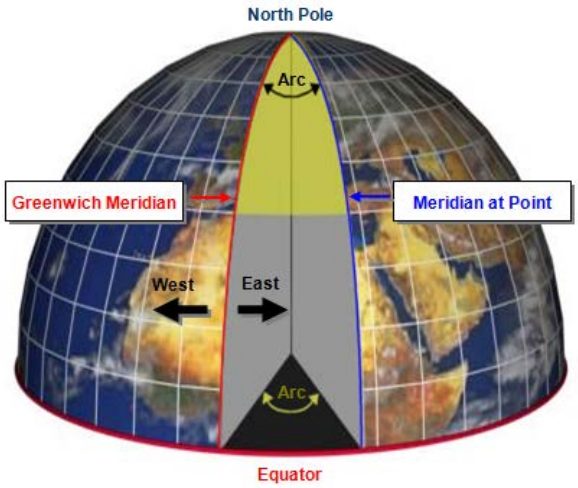
A Great Circle is defined as a circle on the surface of a sphere whose centre and radius are those of the sphere itself. This means that the plane of the great circle passes through the centre of the sphere, dividing it in equal parts.



A meridian is a semi-great circle joining the two poles. Each meridian, together with its anti-meridian completes a great circle and indicates north-south direction. (The true north reference datum is along any meridian, towards the North Pole).

There is no natural datum to start numbering meridians from. The meridian of Greenwich was adopted as the prime meridian at the international meridian conference, held in Washington D.C. in October 1884.

Greenwich is an ancient village, now an area in greater London, England. It is the site of the original Royal Observatory and the prime meridian (or meridian 000°) passes through it



Longitude is defined as the arc of the equator between the meridian through the point and the meridian at Greenwich.

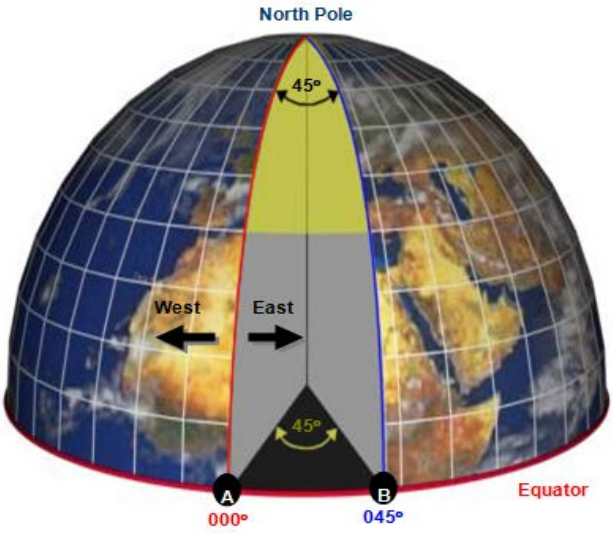
Measurement is taken west or east from the Greenwich meridian in degrees, minutes and seconds.

The anti-meridian of Greenwich is the maximum longitude possible, i.e. 180° east/west.

2.2.6 Change in Longitude

The change in longitude (ch Long) is the same as "difference in longitude (d long)" and is defined as the smaller arc of the equator, intercepted between two meridians.

Example 1 The ch Long between point A on the equator (Greenwich – 000° meridian) and point B along the 045° East meridian measures 45°. (I.e. d long = 45°).



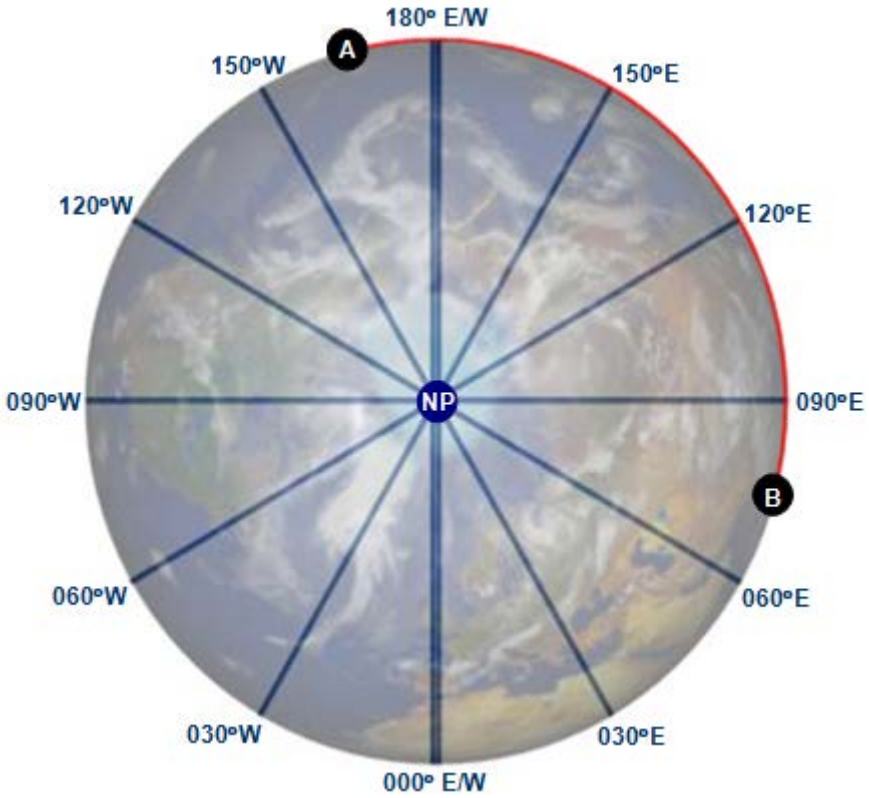
Example 2 Determine the change in longitude (ch long) between the 165° west meridian at (A) and the 075° east meridian at (B).

The answer is 120°.

Let's look at the calculation.

The definition for the change in longitude stated that the ch long equals the "difference in longitude (d long)" and is defined as the smaller (shorter) arc of the equator intercepted between two meridians of two places.

The shortest distance between A and B:



Passing via the anti-meridian (180° east/west) from the 165° west meridian at (A) to the 075° east meridian at (B).

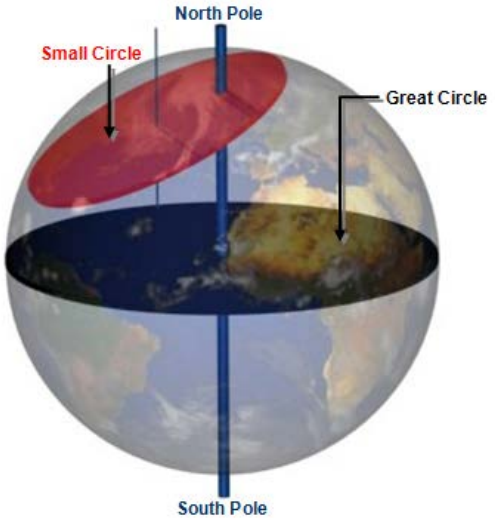
180° - 165° = 15° and
180° - 75° = 105°

∴ 15° + 105° = 120°

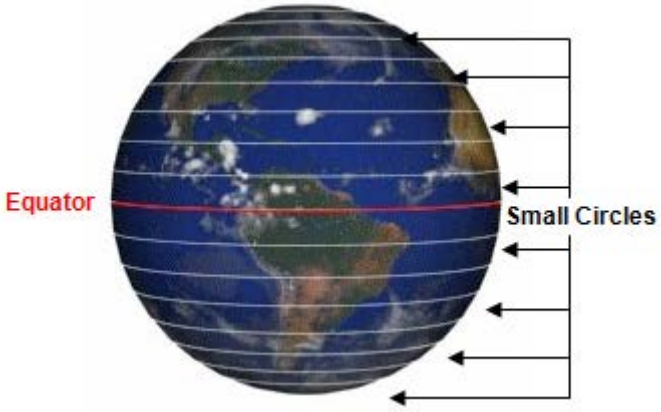
ch long = 120°

2.2.7 Latitudes

A Small Circle is defined as any circle on the surface of the earth whose centre and radius are not those of the earth itself. All circles other than great circles on the surface of a sphere are small circles.



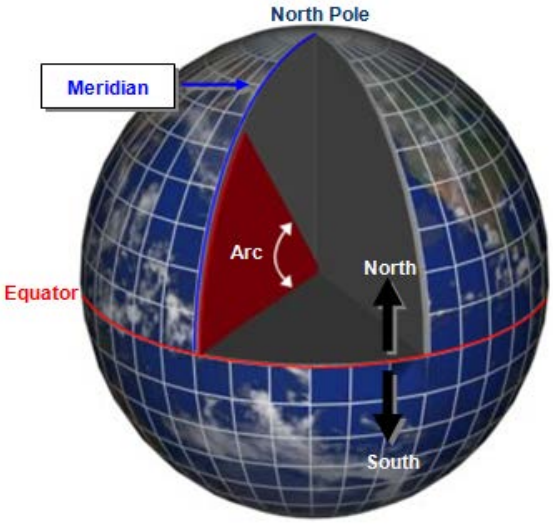
Parallels of latitude are small circles on the surface of the earth whose planes are parallel to the plane of the equator. (Therefore lie in an east-west direction).



Parallel of latitude, other than the equator, is a small circle. The equator is the only great circle to be a parallel of latitude, also marking the origin of measurement (00°N/S).

Latitude is defined as the arc of the meridian, intercepted between the plane and the equator. It is measured in degrees, minutes and seconds north or south of the equator.

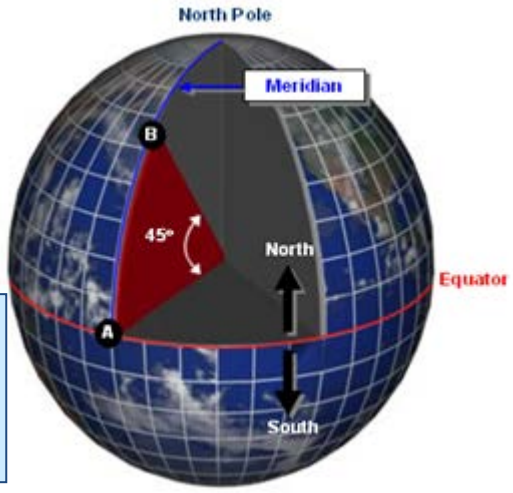
The choice of the equator as a datum of measurement is a natural one, on account of having the largest circumference of all parallels of latitude.



As the planes of all other latitudes lie parallel to the plane of the equator, the arc of the circle from the equator to either pole will be 90° north or south.

2.2.8 Change in Latitude

The change in latitude (ch Lat) is the same as "difference in latitude (d lat)" and is defined as the arc of the meridian, intercepted between the parallels of two places and is expressed as an angular distance in degrees, minutes and seconds.



Example 1: The ch Lat between point A on the equator, and point B along a meridian to the 45° northern latitude measures 45°. (I.e. d lat = 45°).

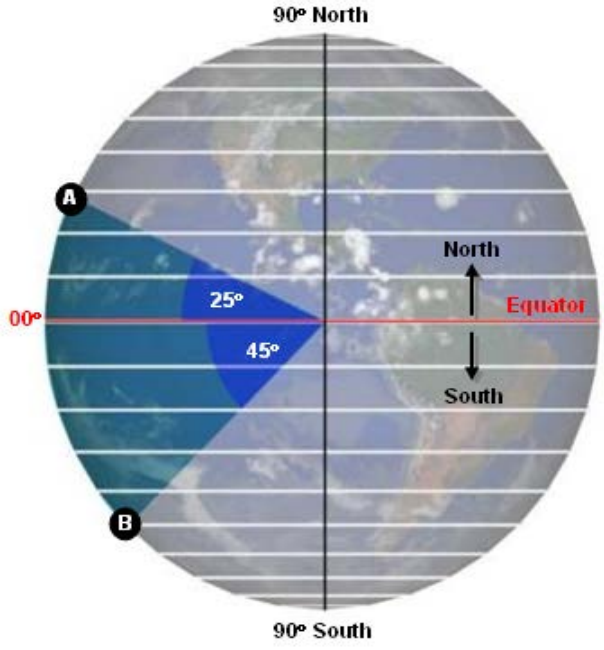
Example 2: Determine the ch lat between the 25° north parallel of latitude at (A) and the 45° south parallel of latitude at (B).

The answer is 70°.

The definition for the change in latitude stated that the change in latitude (ch Lat) is the same as "difference in latitude (d lat)" and is defined as the arc of the meridian, intercepted between the parallels of two places, and is expressed as an angular distance in degrees, minutes and seconds.

The distance between A and B:

Passing the equator (00° north/south) from the 25° north parallel of latitude at (A) to the 45° south parallel of latitude at (B).

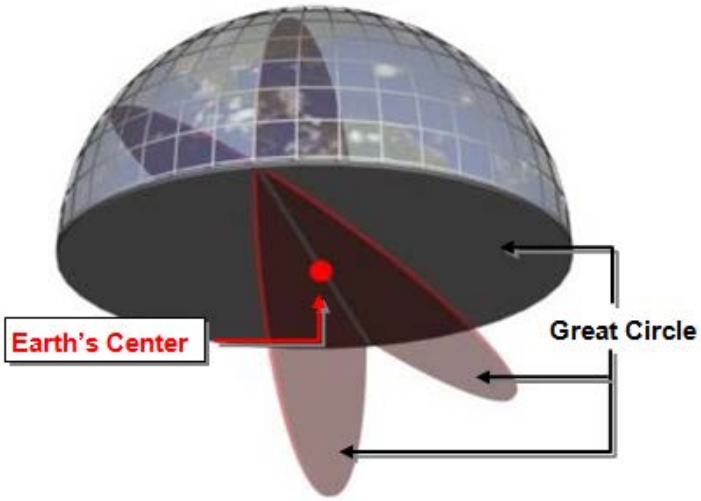


25° + 45° = 70°

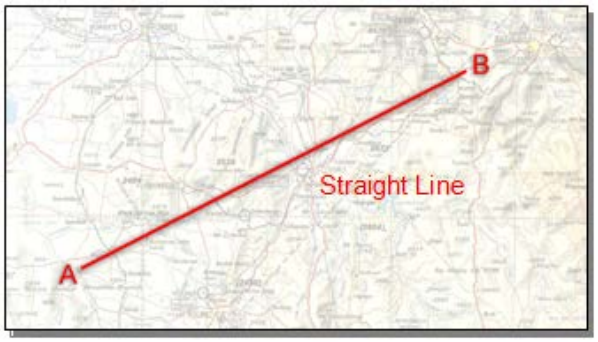
Thus giving us a ch lat of 70°.

2.2.9 Great Circles and Rhumb Lines

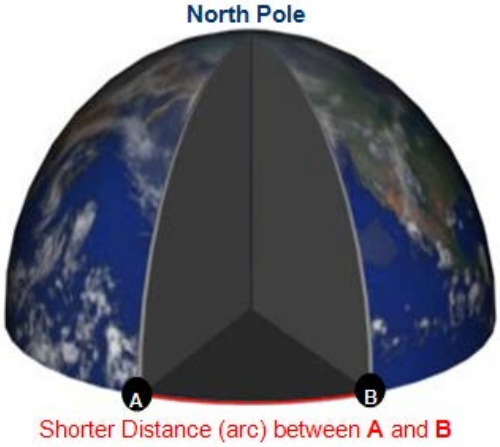
A Great Circle, also known as an Orthodrome, is a circle drawn on the surface of a sphere whose centre and radius are those of the sphere itself. A Great Circle divides the sphere into equal halves.



On a flat surface, the shortest distance between two points is a straight line.

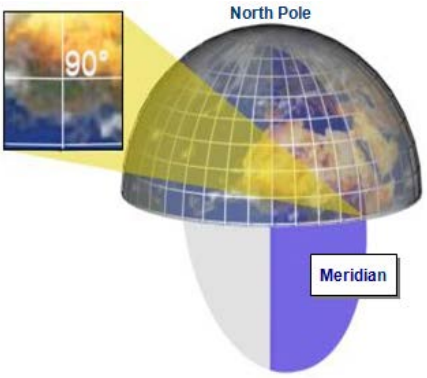


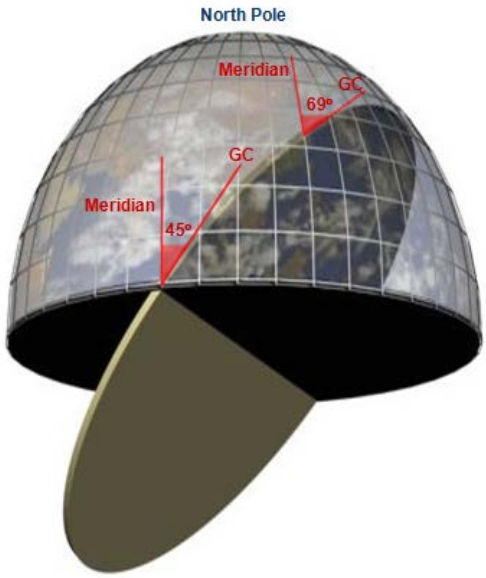
On the earth's surface, the shorter distance between two positions is the shorter arc of the Great Circle passing through the two positions. Only one great circle can be drawn through any two given points, unless the points are direct opposite sides of the sphere.



A semi great circle (meridian) cuts the equator and parallels of latitude at a constant angle of 90°.

This is only true when great circles are drawn so as to pass through the poles. Drawing a great circle anywhere else through two positions will cut the equator and meridians at changing angles.



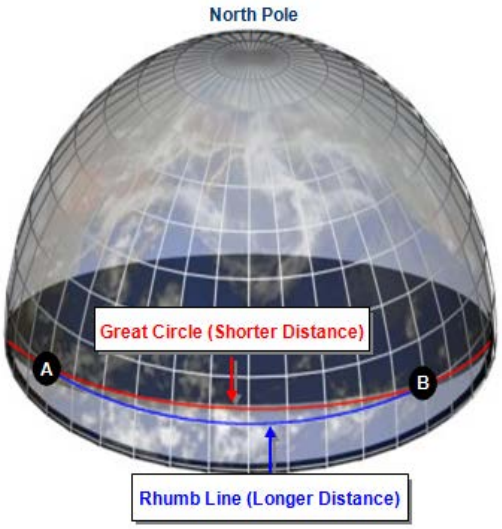


This is illustrated by drawing a great circle to cut the equator at 45°, resulting in changing angles thereafter when passing through meridians.

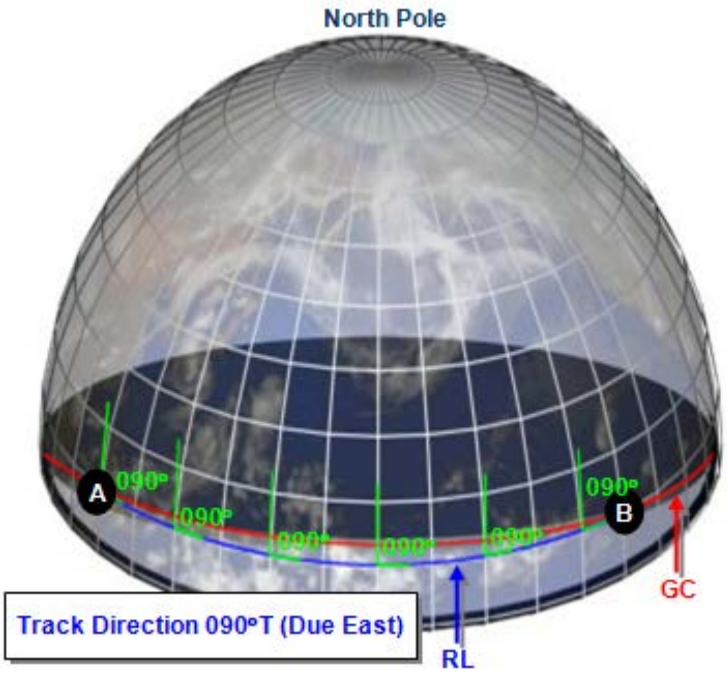
To fly the shortest distance between two places fly the great circle track. The changing angles make such a flight difficult, unless flying due north or south along a meridian.

Drawing a line on the surface of the earth from point A to B, that cuts meridians at the same angle, will result in a constant track direction and indicates a greater distance to be flown. Such a line will appear as a curved line and is called a **Rhumb Line (RL).**

The meridians and equator are the only examples of great circles that are also RL (as a constant direction is maintained when flown). As is the case with great circles, only one RL can be drawn between two positions.

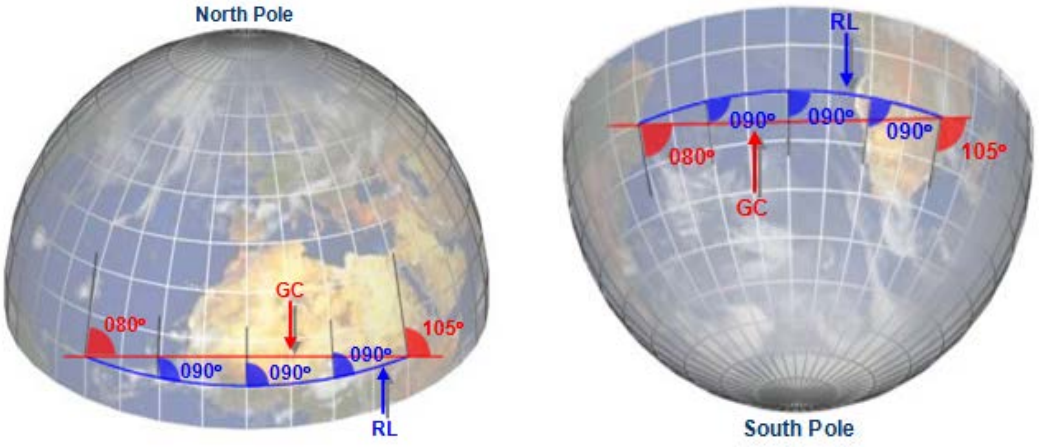


All meridians and parallels of latitude intersect each other at 90°. As the angle is constant, and referring to the definition of a RL, it is clear that flying along a parallel of latitude, a RL track is flown (constant direction).



2.2.9.1 Rhumb Line and Great Circle Relationship

In order to maintain a constant direction (RL) in the northern hemisphere, a track is flown that curves towards the equator (Rhumb Line track). The same is true in the southern hemisphere.



Rhumb Lines curve towards the equator (constant direction and greater distance).

Great Circle Lines indicate changing direction and shorter distance.

However, on a chart that projects meridians as straight lines, parallel to each other, a straight line will be a RL and not a great circle (i.e. cutting meridians at a constant angle).

An example of such a chart is the normal Mercator projection where RLs appear as straight lines and Great Circles as curved lines.

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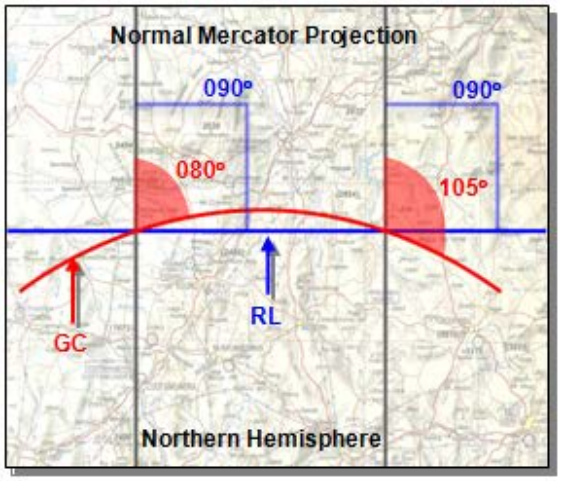
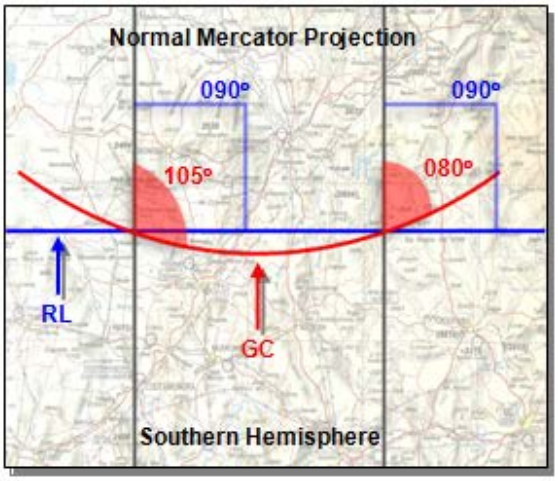




2.2.10 Summary

Meridians	Semi-great circles joining the north and south poles, indicating true direction (true north-south).
Equator	The only parallel of latitude that is a great circle, indicating east-west direction.
Ch Lat & Ch Long	A change in latitude (ch Lat) is measured along a meridian. A change in longitude (ch Long) is measured along a parallel of latitude.
Great Circles & Rhumb Lines	Flying a Great Circle results in changing direction and shortest distance. Flying a rhumb line results in a constant direction and greater distance.

2.3 Methods of Plotting a Position

2.3.1 Introduction

Presenting positions:

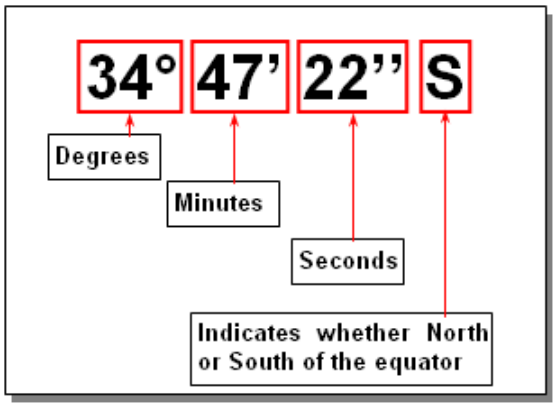
- Latitude and longitude system
- A grid system referred to as the GEOREF system
- Bearing and distance from a known point.

In this section the latitude and longitude system is discussed. You will be given a set of coordinates in degrees, minutes and second and be required to plot these on a chart.

2.3.2 Using Latitude and Longitude

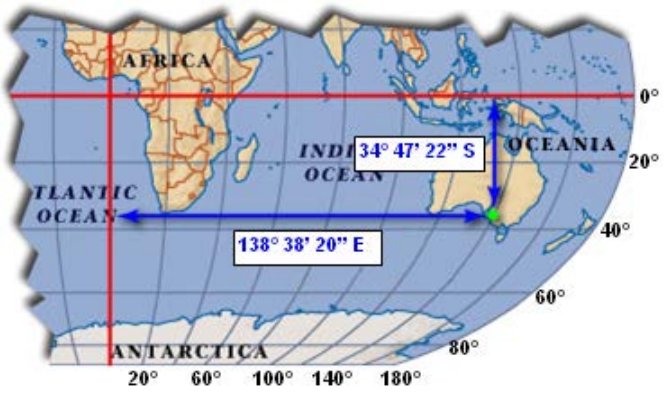
The use of the latitude (Lat) and longitude (Lon) system makes use of a grid, referred to as the lines of latitude and longitude.

A reference is given in two parts, first the latitude and then the longitude.



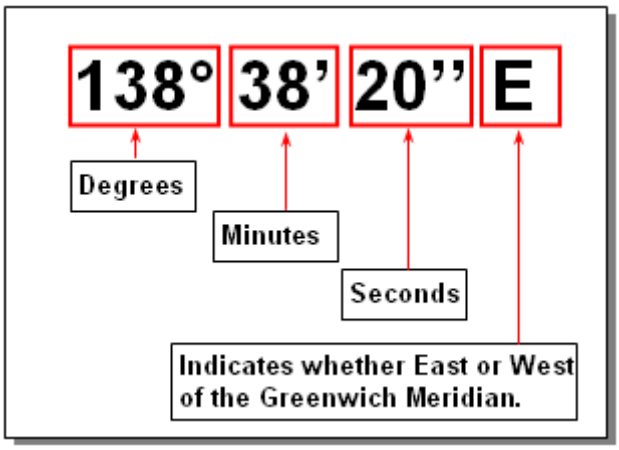
Latitude consists of degrees, minutes and seconds north or south of the equator.

Latitude reference:



Longitude consists of degrees, minutes and seconds east or west of the Greenwich meridian.

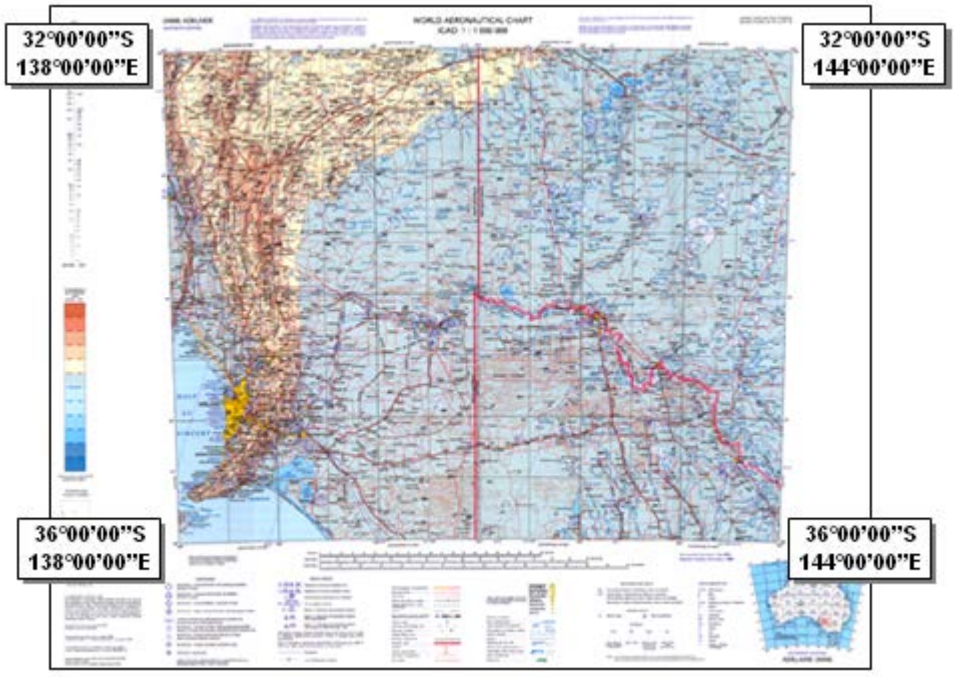
Longitude reference:



A chart, depending on the scale, will cover a range of latitude and longitude. An example indicating the plotting of a position will be shown using a 1:1 000 000 chart (WAC) and a 1:250 000 scale chart (VTC).

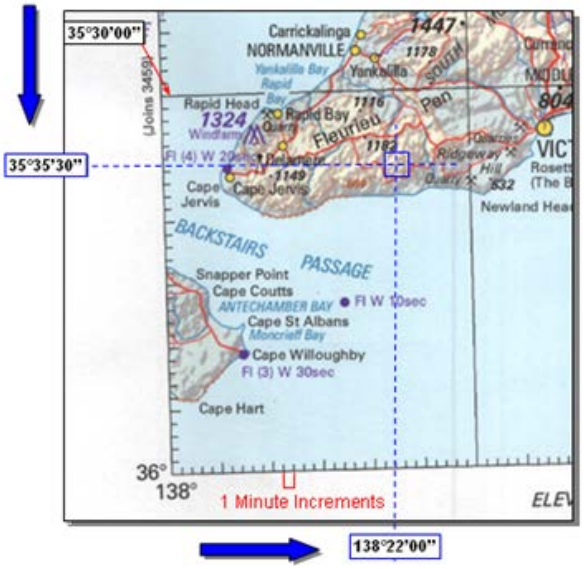
2.3.2.1 1:1 000 000 Chart – (WAC)

Adelaide 1:1 000 000: The chart covers a region from 32°00'00''S to 36°00'00''S and from 138°00'00''E to 144°00'00''E.



Plot the position **35°35'30''S 138°22'00''E**

- Determine the latitude. On the scale on the left of the map, find the point 35°35'30''S, draw in line parallel to the increments.



- Using the scale at the bottom of the map, find the point 138°22'00''E and draw in a line parallel to the increments.

Where the two lines cross is the position **35°35'30"S 138°22'00"E**.

2.3.2.2 <u>1:250 000 Chart – (VTC)</u>

Melbourne 1:250 000 VTC: The chart covers a region from 37°06'00''S to 38°30'00''S and from 144°13'00''E to 145°30'00''E.

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The method of plotting on the larger scale map is the same, only the spacing of the increments changes.

The position **37°14'30''S 145°17'00''E** is plotted above.

No matter what the scale, the process of plotting using latitudes and longitudes remains the same. Keep in mind that on the very small scale maps, the increments may be anything from 5 to 15 minutes.