



DOCUMENT  
**GSM-G-CPL.026**

DOCUMENT TITLE

**NAVIGATION 1**

**CHAPTER 3 – DISTANCE**

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## DISTANCE

### 3.1 Introduction

The simplest explanation (definition) for distance is the length of a line joining two points.

The most well-known form of distance is the road distance between two points and this distance is measured in kilometres or miles. In aviation distance is measured along straight lines and usually measured in nautical miles.

What becomes apparent is that distance is measured in various units (depending on its use).

In the aviation it would be ideal to measure distance in units that are accepted worldwide and that are comparable to laid down existing geographic grid networks.

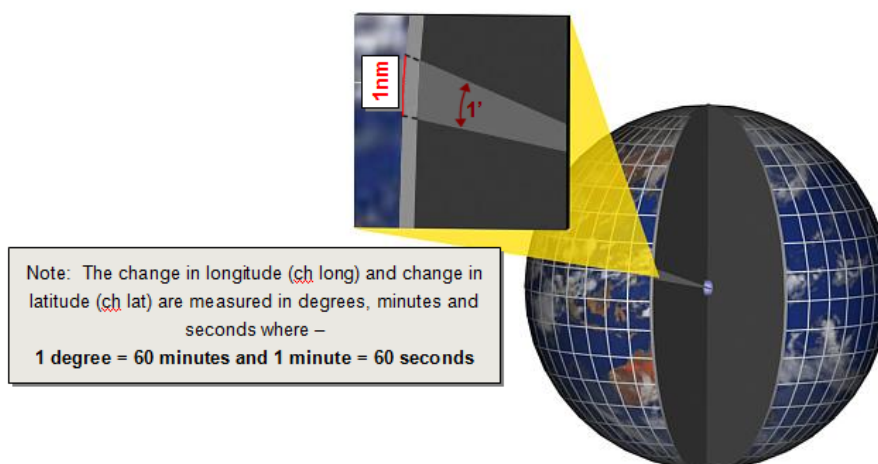
Unlike motor cars that are moving in a fixed environment, aircraft are flown worldwide and using different measurements become a risk for safety.



### 3.2 Distance Measurement Units

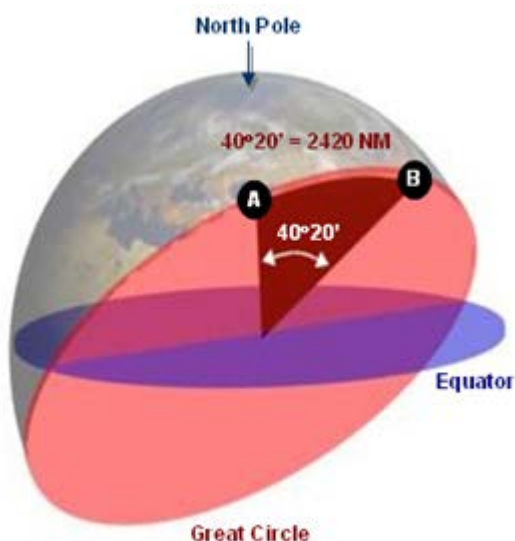
#### 3.2.1 Nautical Mile

Assuming the Earth to be a true sphere, a **nautical mile (nm)** is defined as the average length of the arc of a great circle, which subtends an angle of **one minute** at the centre of the Earth.



In spherical calculations it is frequently convenient to express spherical distances (i.e. great circle distances) in terms of angular measurement rather than linear units.

This is possible because of a simple relationship between the radius, arc and the angle at the centre of a circle.



The length of the arc of a great circle on the Earth may be expressed as  $40^{\circ}20'$ , however, this would convey little unless there were some ready means of converting angular units to linear units.

The conversion from angular to linear units is defined as the standard unit of linear measurement on the Earth, the nautical mile (nm).

The number of nautical miles in the arc of a great circle equals the number of minutes subtended by that arc at the centre of the Earth.

**Example** If an arc on a great circle is  $40^{\circ}20'$  then the distance (in nautical miles) would be equal to **2420 nm**:

$$\begin{aligned}
 40^{\circ} &= (40 \times 60) \text{ min} \therefore 2400 \text{ min} \\
 2400 \text{ min} + 20 \text{ min} &= 2420 \text{ min} \\
 2420 \text{ min} &= 2420 \text{ nm}
 \end{aligned}$$

The conversion of an angular measurement of a great circle distance to linear units requires only the reduction of the angle to minutes of arc. The number of minutes is equal to the spherical distance in nautical miles.

$$1 \text{ minute} = 1 \text{ nautical mile} = 6\,076 \text{ feet}$$

In practice this rule applies to North-South distances along any meridian, since all meridians are great circles.

With reference to east-west distances measured along the parallels of latitude, only the equator is a great circle, therefore only along the equator will 1 minute of longitude be equal to 1 nautical mile.

Other parallels of latitude the east-west distance along the parallel of latitude (small circle) will be less than the ch Long expressed in minutes, therefore 1 minute of longitude will be less than 1 nautical mile.

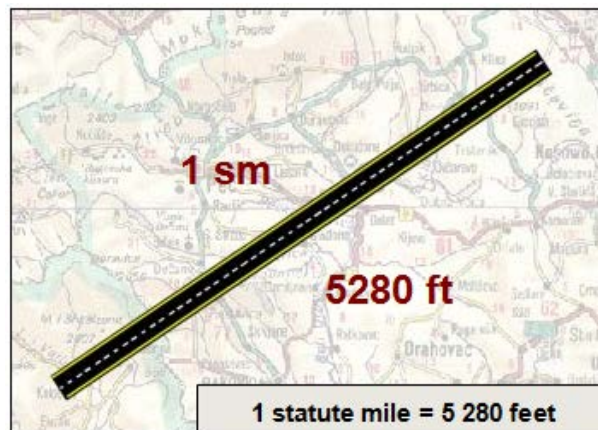
When the ch Long between the 080°W and 010°E meridians is examined at three different latitudes.



The ch Long remains 90° at all three latitudes, however the nautical mile distance between the meridians would be greatest at the equator ( $90^\circ \times 60 = 5400$  nm), reducing with latitude to zero at the poles at a non-linear rate.

### 3.2.2 The Statute Mile

The statute mile (sm) was established by the Royal Decree of Queen Elizabeth I as the standard length of 5280 feet.



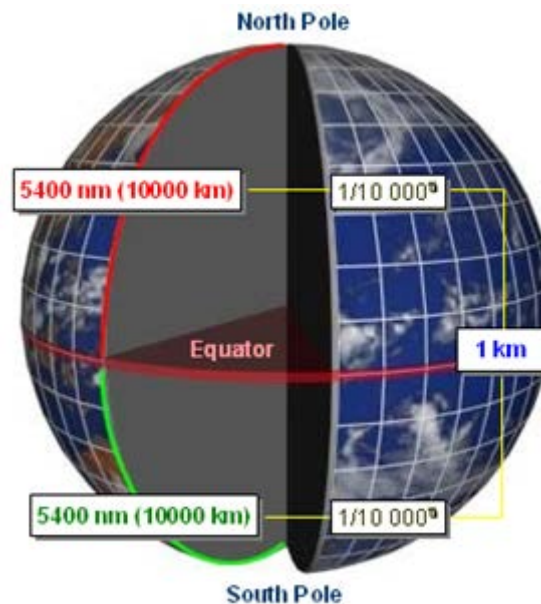
The application of the statute mile for navigational purposes is limited as it involves difficult and cumbersome calculations to convert degrees of latitude and longitude to statute miles.

The statute mile was used mainly in English speaking countries, while internationally; (mainly in the western world) all the navigation facilities and aids such as maps, satellite navigation aids and global positioning systems are using the nautical mile as the standard distance measuring unit.

### 3.2.3 The Kilometre

A **kilometre (km)** is equal to 1000 metres and is a metric unit equal to 3280 feet.

The kilometre is generally accepted as being the length of 1/10,000th part of the average distance between the Equator and either Pole.

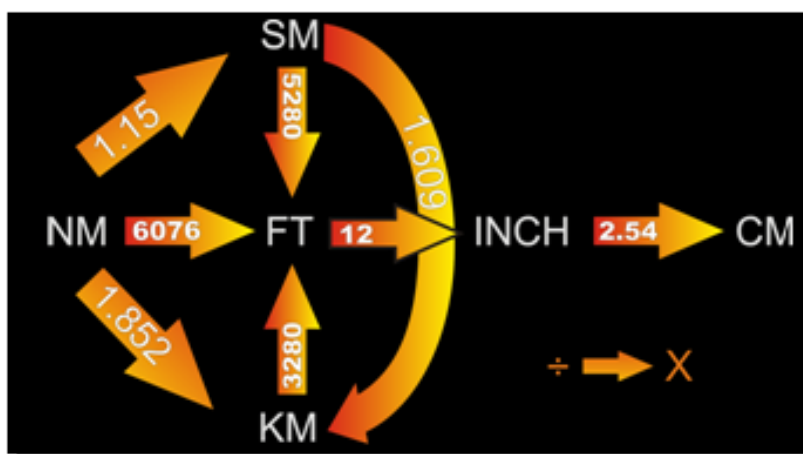


As the distance between the equator and the poles are 5400 nm (or 10,000 km), it follows that 54 nm = 100 km.

**1 kilometre = 3 280 feet**

### 3.3 Distance Conversion

When converting from one unit to another, make use of the following basic conversion factors:



Examples

Conversion of nautical miles to statute miles

$$10 \text{ nm} = ? \text{ sm}$$

$$10 \text{ nm} = 60\,760 \text{ feet } (10 \times 6076)$$

$$60\,760 / 5280 = \mathbf{11.55 \text{ sm}}$$

Conversion of nautical miles to kilometres

$$10 \text{ nm} = ? \text{ km}$$

$$10 \text{ nm} = 60\,760 \text{ feet } (10 \times 6076)$$

$$60\,760 / 3280 = \mathbf{18.52 \text{ km}}$$

Conversion of statute miles to kilometres

$$10 \text{ sm} = ? \text{ km}$$

$$10 \text{ sm} = 52\,800 \text{ feet } (10 \times 5280)$$

$$52\,800 / 3280 = \mathbf{16.1 \text{ km}}$$

Conversion of kilometres to nautical miles

$$10 \text{ km} = ? \text{ nm}$$

$$10 \text{ km} = 32\,800 \text{ feet } (10 \times 3280)$$

$$32\,800 / 6076 = \mathbf{5.4 \text{ nm}}$$

The Jeppesen manual offers an alternative method to perform certain types of unit conversions.

The reference table to the right can be found in the distances section (Tables and Codes tab) of the Australian Jeppesen. The table is used to convert nautical miles into either kilometres or statute miles:

- Enter the centre column with the nautical mile value (interpolating if required).
- Read in the same row to the left the equivalent value in kilometres (interpolating if required).
- Read in the same row to the right the value in statute miles (interpolating as required).

NAUTICAL MILES		
to KM		to SM
1.8520	1	1.1508
3.70	2	2.30
5.56	3	3.45
7.41	4	4.60
9.26	5	5.75
11.11	6	6.90
12.96	7	8.06
14.82	8	9.21
16.67	9	10.36
18.52	10	11.51
37.04	20	23.02
55.56	30	34.52
74.08	40	46.03
92.60	50	57.54
111.12	60	69.05
129.64	70	80.56
148.16	80	92.06
166.68	90	103.57
185.20	100	115.08
370.40	200	230.16
555.60	300	345.23
740.80	400	460.31
926.00	500	575.39
1111.20	600	690.47

There are various other conversion tables available in this section of the Jeppesen and is used in a similar manner.



### 3.4 Measuring Distance

#### 3.4.1 Using a Navigation Ruler

In Australia distance is measured in nautical miles.

On most topographical maps, the distance between two places is usually measured using a navigation ruler. A navigation ruler may have several scales. It is important to use the correct scale for the type of map used. The scale of the map must match the scale available on the navigation ruler.

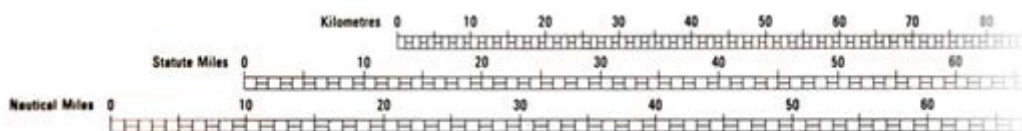


Using the VNC the distance would be measured with the centre scale of the ruler shown above.

Rulers may present various scales, e.g. nautical miles, kilometres and statute miles for each of the scales offered. With these navigation rulers the user must take care not only to select the correct scale, but also the unit the distance is to be measured in.

#### 3.4.2 Using the Scale Diagram on the Map

Scale diagrams are depicted on the bottom of topographical maps and may be used to measure distance.



These scaled diagrams match the scale of the map. Select the correct scaled line, matched to the distance unit to be used for measurement.

The scale diagram method can be used when the scales available on the navigation ruler do not match the scale of the map.

#### 3.4.3 Using the Latitude Scale to Measure Distance

The latitude scale may also be used to measure distance.

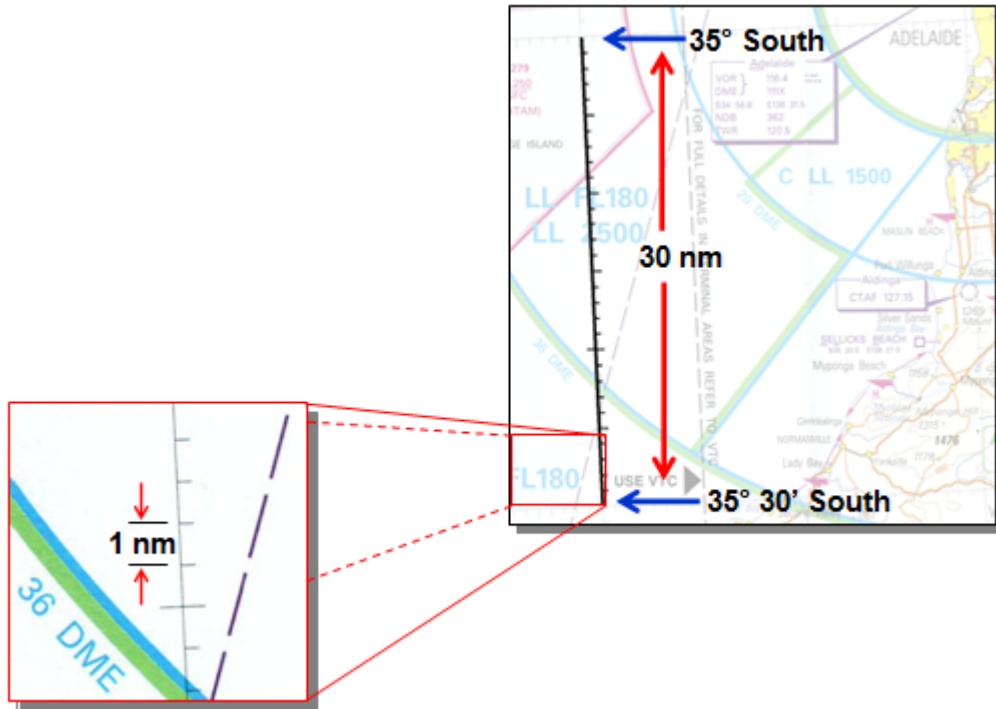
This technique is required if the map does not have a scaled distance diagram and the scales available on the navigation ruler do not match the scale of the map. It is also the most accurate method for measuring distances on maps.

With this method the distance between the two points is compared with the latitude scale (along the meridians) depicted on the map.



One degree of latitude equals 60 minutes and one minute of latitude is equal to one nautical mile.

The distance between 35° south and 35° 30' south is 30 nm. Each graduation is equal to one minute; therefore one minute of latitude equals one nautical mile.



The latitude scale spacing on maps differ and should be examined before the distance is measured. Maps that cover large areas in little detail (Jeppesen en route charts) tend to have graduations for minutes of latitude every 5 or 10 minutes (5 nm and 10 nm respectively), whereas maps that are more zoomed in (less area and more detailed) tend to have latitude markings every minute.

The topographical maps used in visual navigation (Australian VTC, VNC and WAC) have latitude markings for every minute of latitude, simplifying the distance measurement process.

**Note** The horizontal scale (longitude scale) is not used to measuring distance.