DOCUMENT
GSM-G-CPL.026

DOCUMENT TITLE

NAVIGATION 1

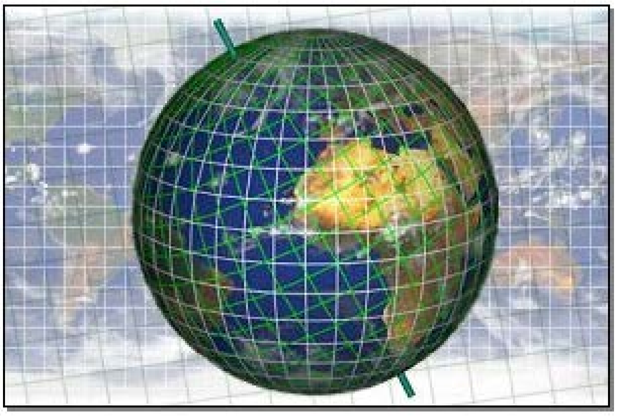
CHAPTER 4 – DIRECTION

Version 2.0
October 2017

CONTENTS

DIRECTION

4.1 Introduction



The process of navigation involves flying a direction for a specific distance. For this reason a method is required to measure direction.

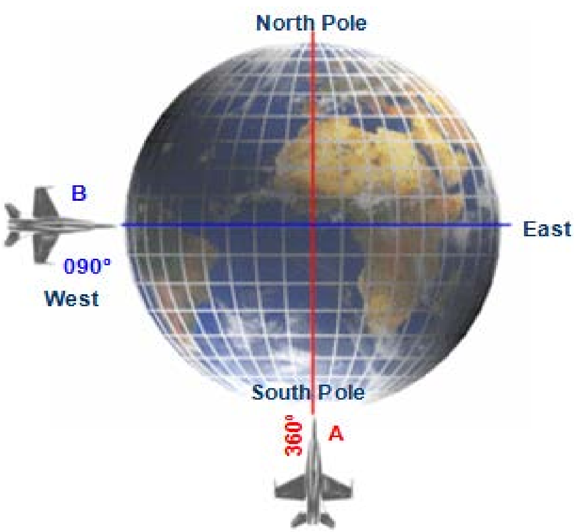
The Earth is "covered" in a net consisting of lines of longitude (meridians) and lines of latitude (parallels of latitude).

The poles are geographically located at either end of the meridians. It is from the geographical location of the Poles and the construction of the meridians (north-south) and parallels of latitude (east-west), that true direction was defined.

The Earth has magnetic properties, therefore another net "covers" the Earth; one that has a different north pole (magnetic north pole) than the true north pole. It would therefore stand to reason that when following the magnetic compass needle a different direction will be flown, than what was originally intended.

Due to the different characteristics of the magnetic field, it is important to distinguish between the different types of direction.

4.2 True Direction



Flying along a meridian (semi great circle) towards the North Pole the aircraft will be flying a true track of 360°T (aircraft A). The letter 'T' represents True direction.

Flying along a parallel of latitude, e.g. west to east (aircraft B), a true track of 090°T is flown (270°T when flying east to west).

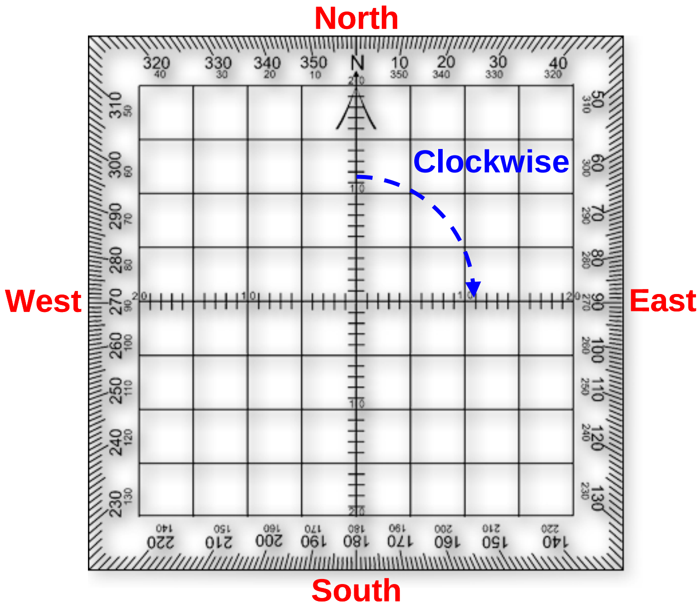
These tracks represent true direction and have a 'T' placed to the right of the degrees e.g. 090°T

When using a magnetic compass the track flown represents a magnetic track; which is in a different direction than true track.

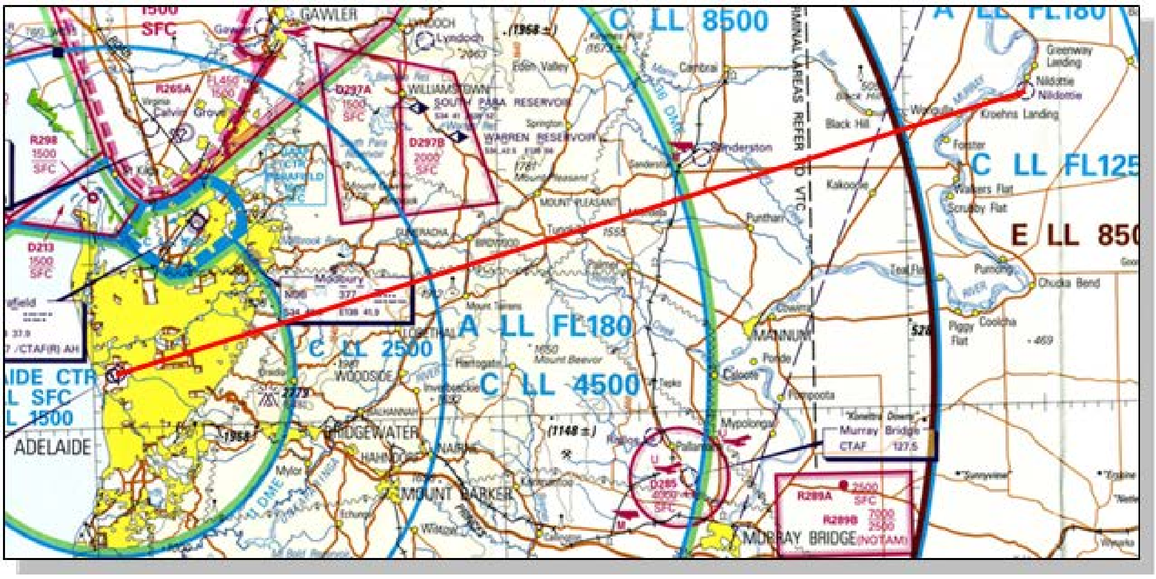
4.2.1 Measuring True Track

Track is the path or route that is flown along the surface of the earth and measured on a map or chart using a protractor.

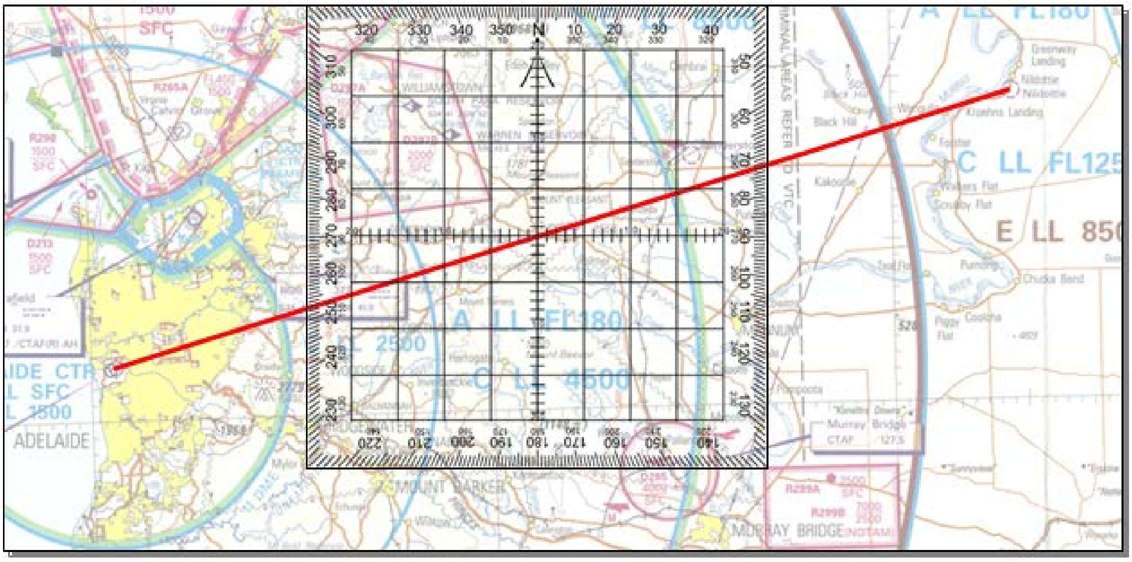
The face of the protractor is marked in degrees from north (000°) in a **clockwise direction** to 360°, north represents both 000° and 360°, 090° East, 180° south and 270° west.



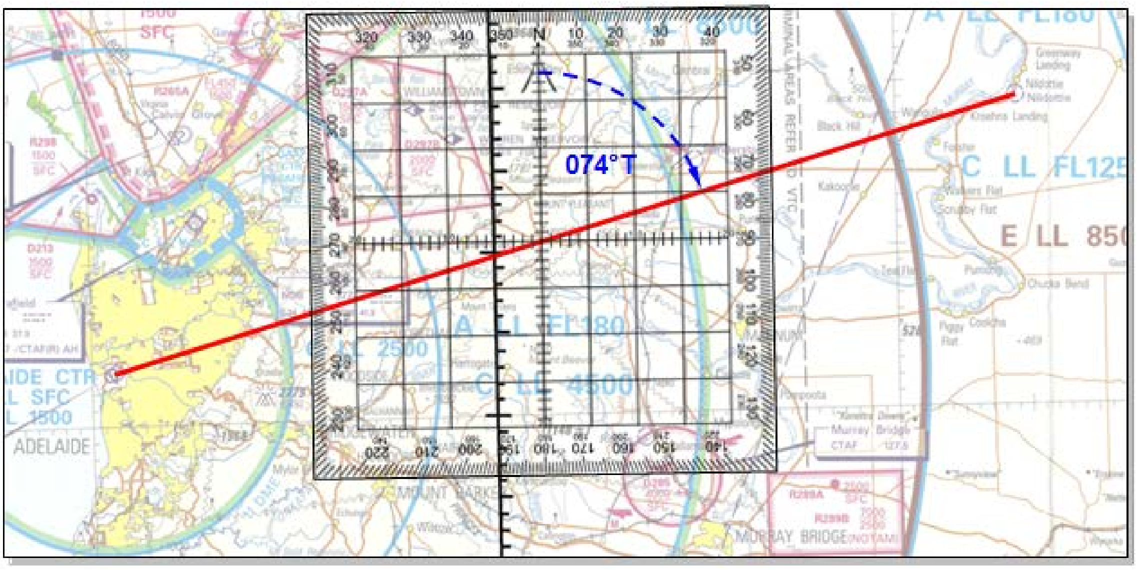
Example A track is drawn from Adelaide airport to Nildottie Airport (red line), connecting the centre of the two aerodrome symbols on the map. (Tracks are usually drawn in black ink).



Place the protractor with north at the top, orientated to where true north is for the map, and place it approximately half way along the track.



Make sure the centre of the protractor is on the track and the vertical lines on the protractor are lined up with or parallel to the meridians.



The track is measured in a clockwise direction from 000° (true north) and the reading taken where the track crosses the outer values on the protractor, e.g. 074°T.

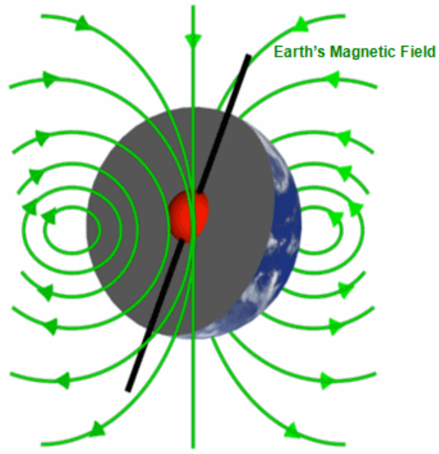
Flying to Nildottie the aircraft should travel in a direction of 074°T from Adelaide Airport.

As aircraft generally use a magnetic system to determine direction the true track is converted to magnetic track.

4.3 Magnetic Direction

4.3.1 Earth's Magnetic Field

Surface rocks, which contain varying amounts of iron oxides, sometimes produce a limited magnetic field, but this has only a local effect. An additional contribution comes from electric currents in the upper atmosphere, but this is limited as well, normally producing less than 1% of the total field.

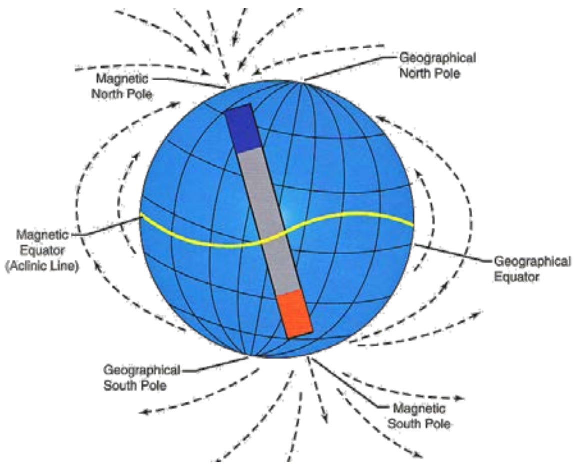


The major source of the field lies deep within the Earth, acting like a dynamo. It is believed that this force field originates from complex patterns of both liquid flow and electric currents in the liquid iron of the outer core.

These electric currents produce a magnetic field that passes through the flowing liquid, generating more electric current in this process.

The sphere of influence of a magnet is called a magnetic field, which is composed of its magnetic lines of force. A magnet lying across the magnetic field of another magnet would tend to take up the direction of the line of force running through it, with the opposite poles nearer to each other.

The Earth behaves as though a huge permanent magnet were situated near the centre producing a magnetic field over the surface. The poles of this hypothetical earth-magnet do not coincide with the earth's spin axis or geographical poles.

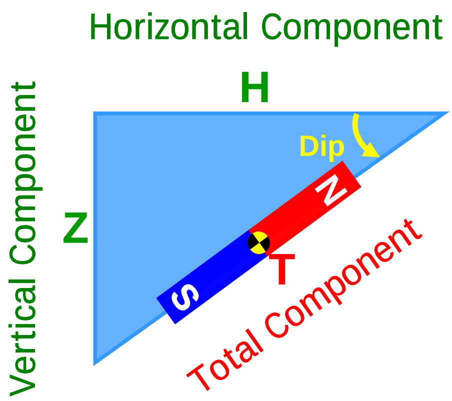


The Earth's magnetic north pole was in 2016 located north of Canada, at approximately 86°N 166°W. In 2015 the magnetic south pole was observed to be close to Antarctica at about 64°S 137°E.

By convention, the north magnetic pole is BLUE and attracts the RED pole (north - seeking end) of the compass needle.

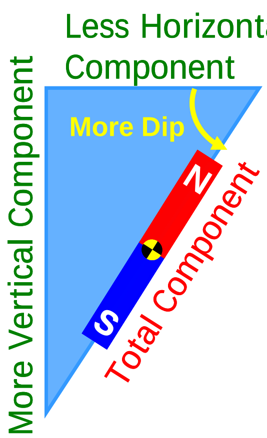
4.3.1.1 Components of the Earth's Magnetic Field

The total force ‘T’ exerted at a point by the Earth's field acts in the direction taken up by a freely-suspended magnet influenced only by the Earth's field. It is convenient to resolve this total force ‘T’ into its horizontal and vertical components ‘H’ and ‘Z’ respectively. The angle, measured in the vertical plane, between the axis of the magnet and the horizontal is called the 'angle of dip'. The diagram below demonstrates this resolution for the Southern Hemisphere at mid-latitudes.

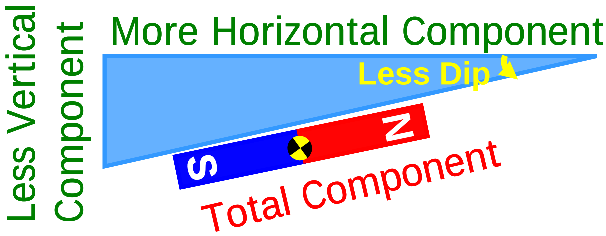


The horizontal component ‘H’ of the Earth's field is known as the directive force as it is the component, which aligns the magnetic compass needle with the magnetic meridian, so providing a directional reference.

When either of the Earth's magnetic poles is approached the component approaches zero strength (while the value of ‘Z’ approaches that of ‘T’). Overhead the pole, with dip 90° and zero directive force ‘H’, the magnetic sensor (compass) becomes unusable. The pictures below represent the southern hemisphere.



In the region of the magnetic equator, the strength of the directive force ‘H’ approaches the value of ‘T’ (directive force is maximum), ‘Z’ and the angle of dip approaches zero.



The directive force decreases as the angle of dip increases and vice versa, consequently near the equator to approximately 70° north or south a compass system works well. With the exception of the magnetic equator where the lines of force are parallel to the surface, one end of the freely-suspended magnet will dip below the horizontal, pointing to the nearer pole. To the north of the magnetic equator, the magnet's north seeking pole will be lower, whereas to the south the magnet’s south seeking pole will be lower.

The magnetic equator is represented by a line on a chart where the magnetic dip is zero. The magnetic equator is curved and is within 10° of latitude of the geographical equator.

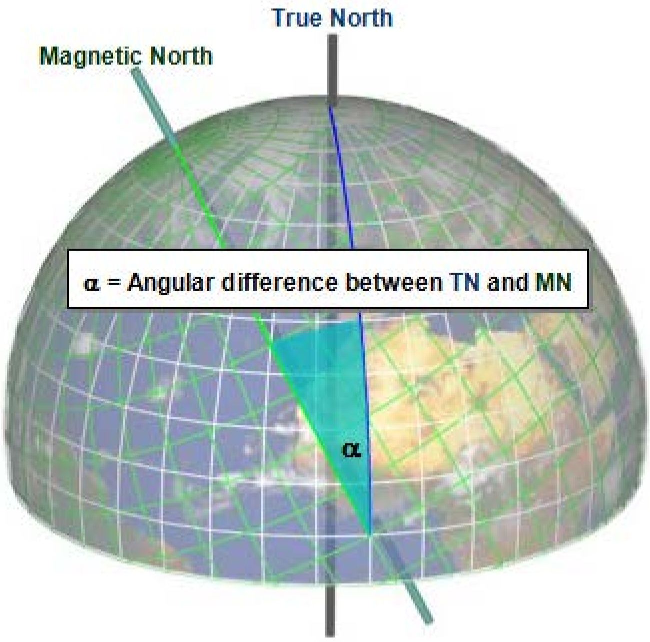
If the freely suspended magnet is moved either north or south of the magnetic equator the dip gradually increases, reaching about 66° in the United Kingdom (latitude 50°00’N) and about 52° at Adelaide in South Australia (latitude 35°00’S). Overhead the Earth's magnetic poles, the dip is 90° and the magnet would be vertical.

The angle of dip affects the magnetic compass susceptibility to acceleration and turning errors. As the angle of dip increases, the amount of error induced in the magnetic compass due to acceleration and turning increases. These errors are discussed detail in the subject, Aircraft General Knowledge (AGK).

4.3.2 Difference between True and Magnetic Direction

Due to the magnetic field surrounding the Earth, a needle of a magnetic compass aligns with the magnetic meridian, indicating magnetic north. The magnetic meridian is the direction of the horizontal component of the Earth’s magnetic field at a point on the Earth’s surface.

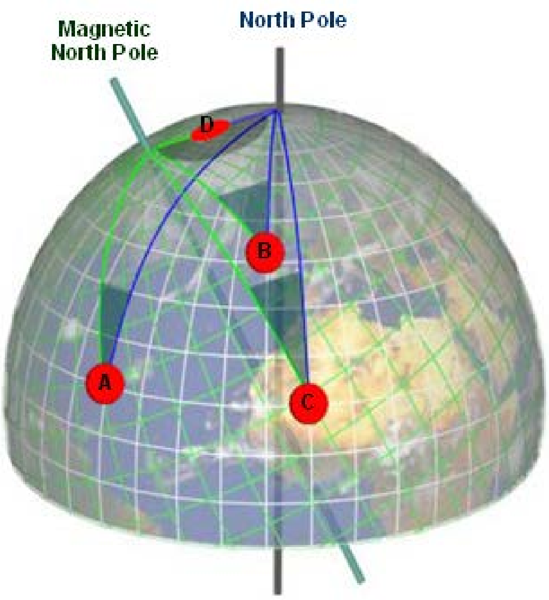
As the magnetic meridian is not aligned with the true meridians on the surface of the Earth, it will result in an angular difference between true direction and magnetic direction. This is of importance when plotting an aircraft’s track on a map. All meridians on maps depict the direction of True north, resulting in a requirement to convert between true and magnetic directions.



The angular difference between the true north and magnetic north is known as 'variation'.

Comparing A, B, and C, this angle varies according to both latitude and longitude. (E.g. A and C are on the same latitude, but their variation differs).

In the extreme case, if situated between the north geographic pole and the north magnetic pole the compass would indicate magnetic north, while pointing due south of the true north pole, see D. In this case the variation would be 180°.



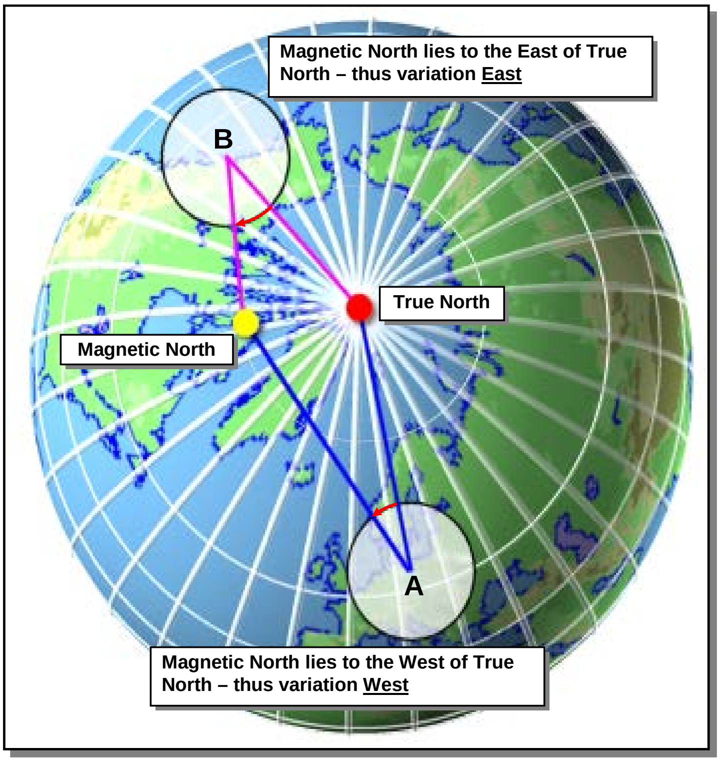
The Earth's magnetic field at any point is defined from the knowledge of its three characteristics, namely:

- Variation
- Intensity
- Angle of dip.

Definition: Variation is therefore defined as the angle between the horizontal direction taken up by a freely suspended magnetic needle under the influence of the Earth's magnetic field alone, and the direction of true north.

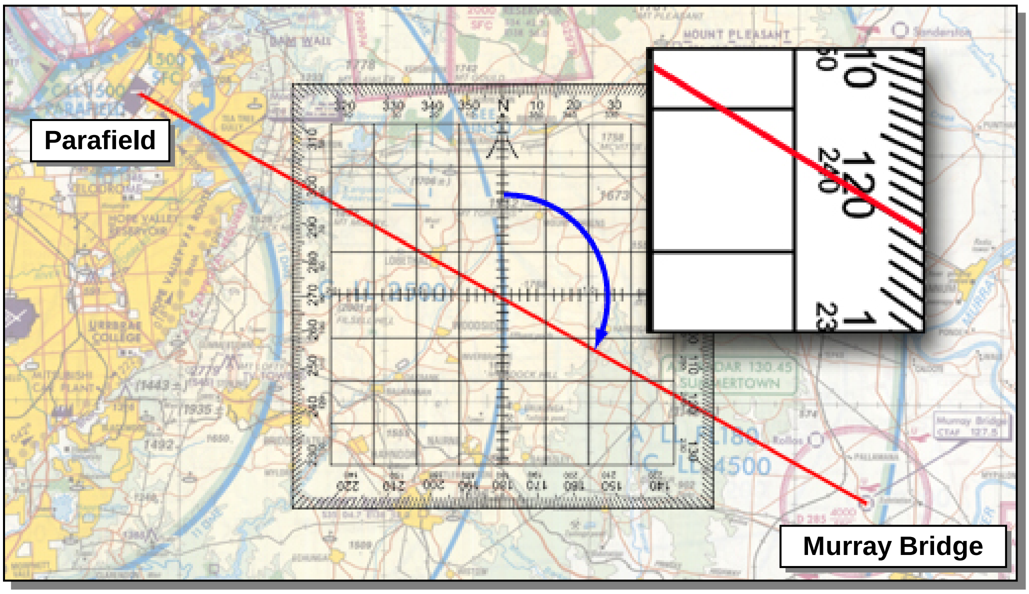
Variation may be east or west depending on which side of true north magnetic north is located and may vary from zero to 180° east or west.

Variation is always measured from true north towards magnetic north.

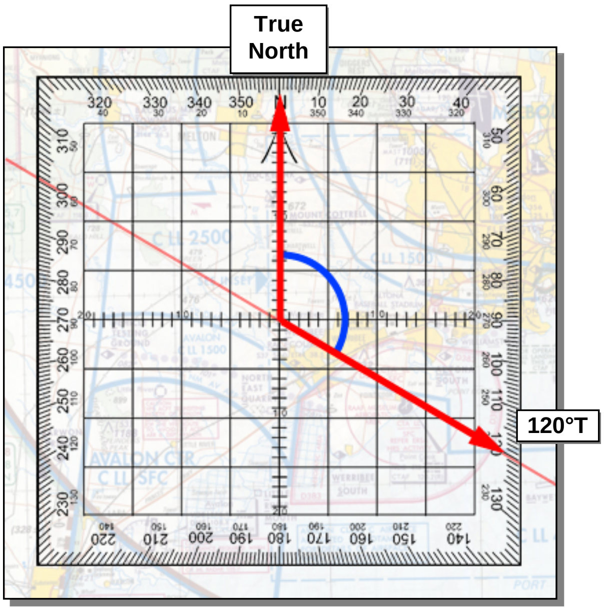


4.3.2.1 Application of Variation

In this example, a track is drawn from Parafield to Murray Bridge. The protractor is aligned with true north using the longitude lines and the centre is placed halfway between the two points. A reading is taken where the track crosses the protractor's edge, a direction of 120°T is measured clockwise from true north.

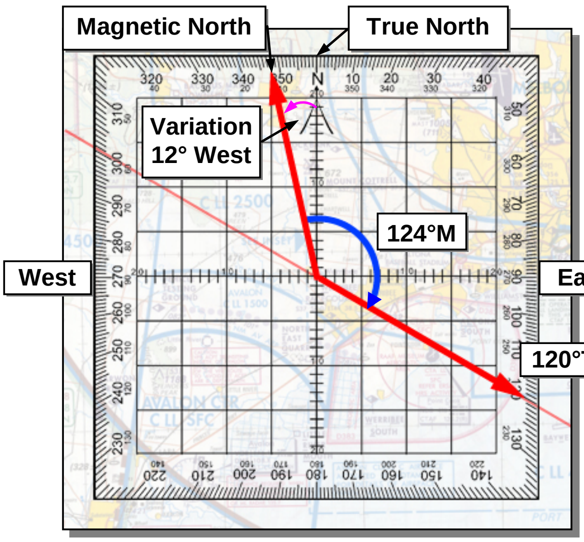


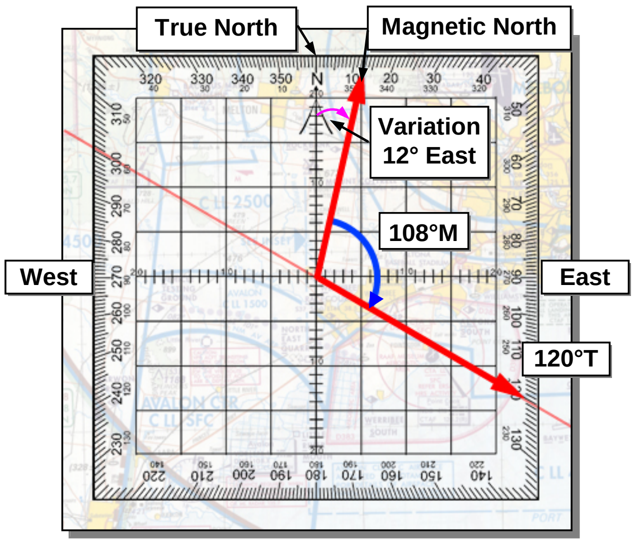
Variation is normally applied to true direction to obtain magnetic direction. The true track is measured using a protractor and variation applied to determine the magnetic track.



If the variation is westerly the value is added to the true track, and if the variation is easterly the value is subtracted from the true track, to obtain magnetic track. The diagrams below illustrate the reason for the addition or subtraction.

The illustration to the left is for westerly variation, where magnetic north is located westwards of true north. To convert the true track direction 120°T to magnetic direction, the westerly variation is added to the true direction.





The angle measured from true north to the track is a smaller angle than the angle measured from magnetic north to the track and hence the magnetic direction must have a greater value, 124°M (M = Magnetic).

In the illustration to the right an easterly variation is depicted, where magnetic north is located eastwards of true north. To convert the true track direction 120°T to magnetic direction, the easterly variation is subtracted from the true direction.

It can also be observed that the angle measured from true north to the track is a greater angle than the angle measured from magnetic north and hence the magnetic direction has a lesser value, 108°M.

Variation West – <u>Magnetic Best</u> (add), Variation East – <u>Magnetic Least</u> (subtract)

The rhyme above only applies for the standard convention of applying variation from true- to magnetic direction. When converting from magnetic- to true direction the **opposite** will apply.

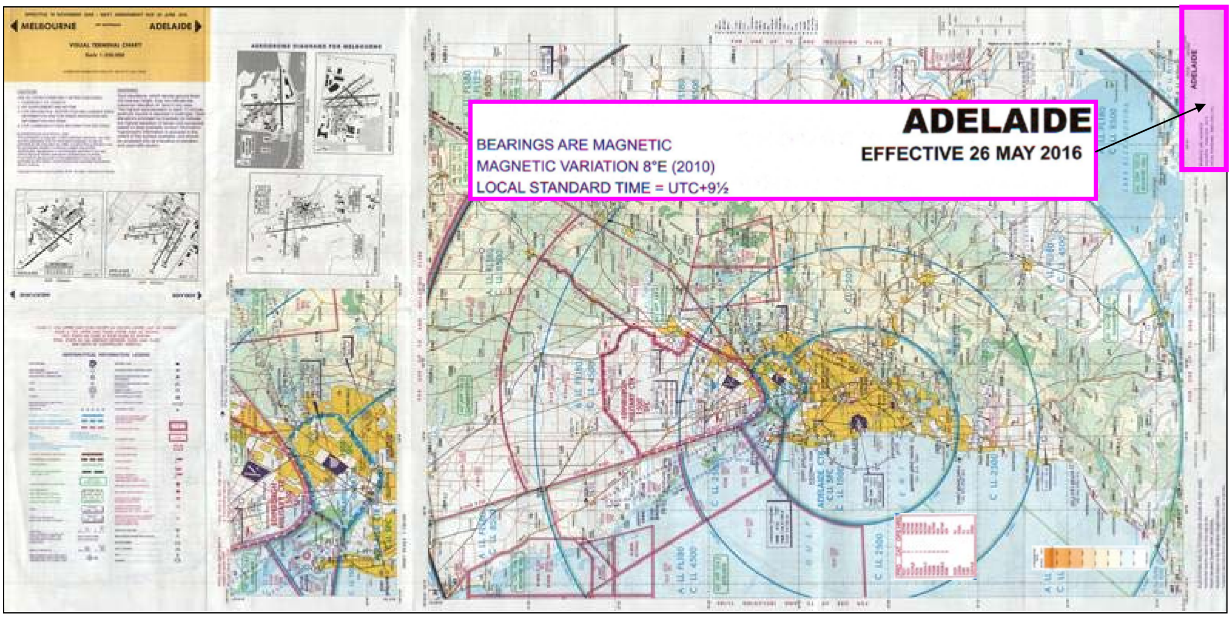
4.3.2.2 <u>Isogonals</u>

An Isogonal is a line along the surface of the Earth where points have the same variation.

Isogonals are usually drawn on all aeronautical charts in the form of curved dashed lines.

In the picture of the world aeronautical chart, the 11°E and 11½°E Isogonals are shown. Isogonals on the VNC and Jeppesen Radio Navigation Charts are shown in a similar fashion.

The Australian VTCs cover a small area and the value of variation does not change by much across the chart. The entire chart may have the same variation and therefore no isogonals are depicted on the chart. Variation is shown as part of the legend.

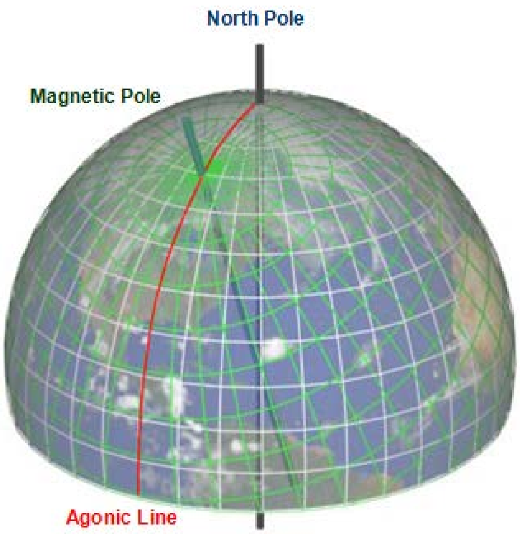


The isogonal (variation value) closest to where the centre point of the protractor was placed to measure the true track direction, is used to determine magnetic direction. It may be necessary for variation values to be interpolated to the nearest whole degree.

To obtain the value for variation to be used during flight, interpolate between the isogonals around the current location of the aircraft.

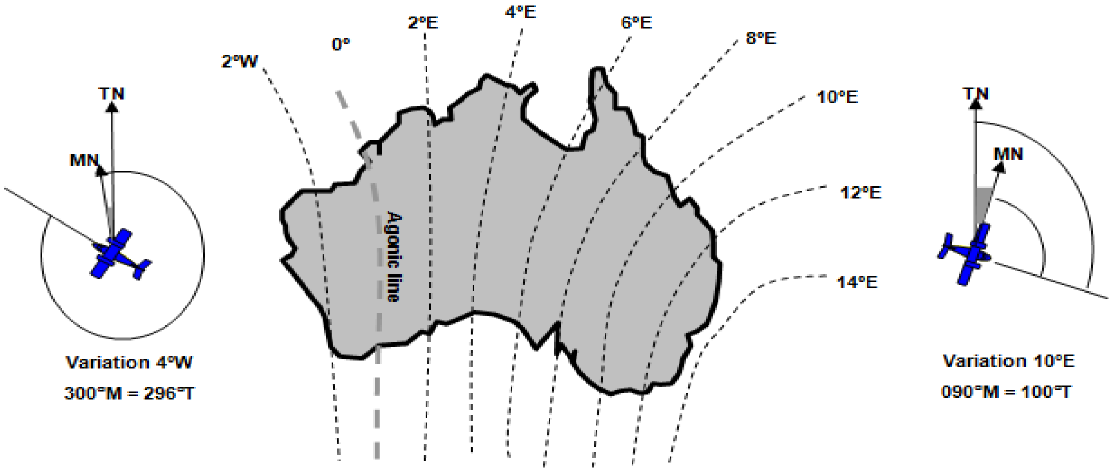
4.3.2.3 Agonic Line

When flying north (red line) the true north pole and the magnetic north pole direction is identical, therefore no angular difference between true north and magnetic north. Any point situated on the line has zero variation.



Definition: An agonic line is a line on the surface of the Earth along which all points have no variation.

An agonic line (Variation 0°) passes through Australia, east of Perth. Note the variation change from a westerly- to easterly variation either side of .the Agonic line.



4.3.3 Regular Changes in Earth Magnetism

The Earth's field lacks symmetry and is also subject to several known periodic changes. The secular changes are the most significant and produced by the slow movement of the magnetic poles about the geographic poles. The period of the cycle is about 960 years. The north magnetic pole is moving slowly westward, this movement mainly affecting magnetic variation.

The agonic line through Western Australia is slowly moving west. The current variation in Perth is 2°W and will reduce to zero over the next 20 to 30 years. The variation in Adelaide (8°E) and Sydney (13°E) will increase at about the same rate. The annual rate of change of variation is shown on navigation charts.

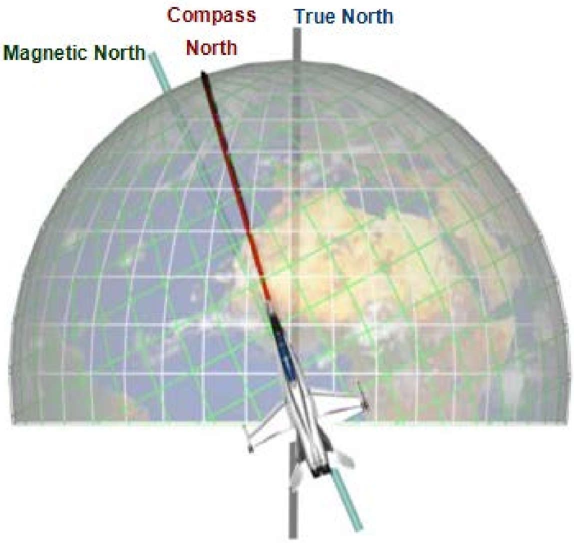
Other regular changes occur diurnally, annually and over an eleven year period, this latter cycle apparently being related to the eleven year cycle of sunspot activity. These changes unlike the secular type mentioned earlier, are not of sufficient magnitude to affect normal navigation.

4.4 Compass Direction

Another factor to consider is that when aircraft are built, a magnetic field is imparted to the airframe due to certain construction methods used (e.g. vibration due to riveting, drilling, etc.).

The magnetic fields generated by the instrumentation and radio equipment must also be taken into consideration.

A magnet lying across the magnetic field of another magnet would tend to take up the direction of the line of force running through it, with the opposite poles nearer to each other. (An aircraft is a magnet due to its magnetic field, and the Earth also has its own magnetic field).



An error will therefore be encountered through this process, the error being that the compass north and magnetic north will also not be in the same position. This error is not constant with all aircraft or compasses and will have to be calculated for each individual airframe and compass combination.

4.4.1 Difference between Magnetic and Compass North

This error implies that a compass north exists, with the angular difference between the compass north and magnetic north being either east or west of Magnetic north. The angular difference measured from magnetic north towards compass north is known as 'deviation'.

Definition Deviation is the angular difference that exists between the magnet meridian and the direction taken up by a particular compass needle, measured in degrees west or east of the magnetic meridian.

The deviation for an aircraft and compass combination varies with both magnetic latitude and heading and is calculated through a procedure known as a compass swing.

During the calibration procedure errors in the compass are compensated for by making adjustments to screws on the compass. Some errors cannot be compensated for and are recorded on a separate card kept next to the compass for reference. The card is known as the compass deviation card:

FOR (HDG°M)	N	030	060	E	120	150	S	210	240	W	300	330
STEER (HDG°C)	002	031	060	089	118	148	179	210	241	272	303	332

7/9/01

During flight the correction card is referenced to compensate for deviation. The difference between magnetic and compass direction is the deviation on that particular heading.

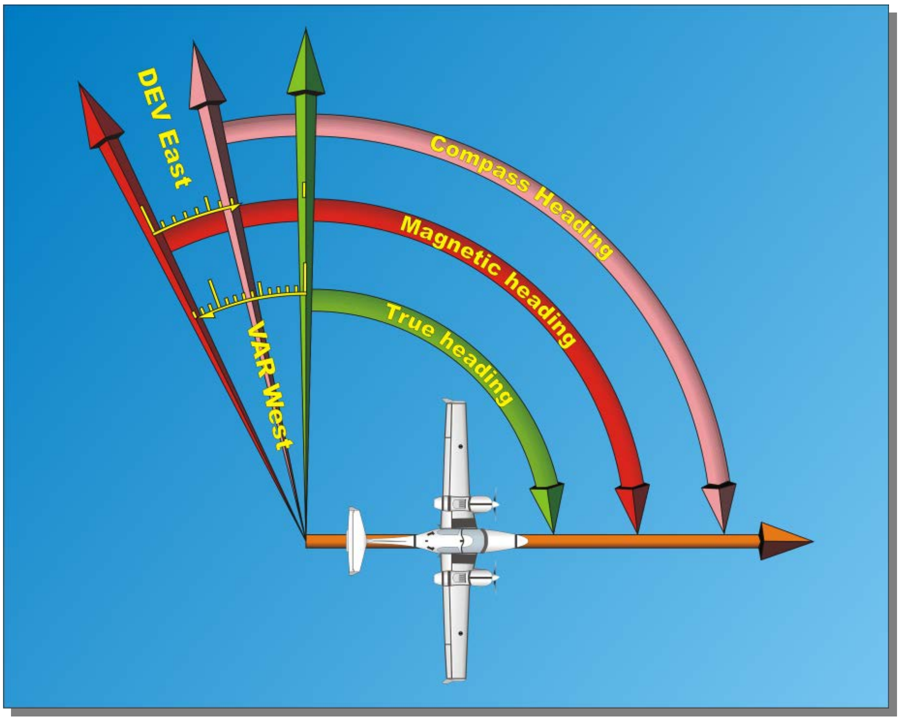
Example if the aircraft is flown towards magnetic north (000°M) then a compass heading of 002°C (C = compass direction) is required to compensate for the error. In this case the deviation would be 2° west.

If a magnetic heading of 310°M is required, the values for deviation are interpolated. In the example above interpolated between the corrections for 300°M and 330°M will be required.

Since 310°M is closest to 300°M on the correction card, the correction as indicated for 300°M is applied to the intended heading of 310°M and hence a compass heading of 313°C will be required as the deviation is assumed to be 3° west.

4.4.1.1 Application of Variation and Deviation

Variation is the difference between true and magnetic direction. Deviation is the difference between magnetic and compass direction.



The green arrow represents true north and the true heading of the aircraft is indicated. Assume the true heading is 090°T, the red arrow representing magnetic north is to the west of true north, therefore the variation is westerly. Assume the variation has a value of 13°W (west) and when the value is applied to the true heading 090°T, the magnetic heading will be 103°M.

The pink arrow represents compass north. Since compass north is east of magnetic north, the deviation would be easterly. Assume the deviation is 7°E (east). Easterly deviation is subtracted from magnetic direction to obtain compass direction and westerly deviation would be added.

In the example, when the easterly deviation of 7°E is applied to the magnetic heading of 103°M, the compass heading would be 096°C.

Deviation West – <u>Compass Best</u> (add), Deviation East – <u>Compass Least</u> (subtract)

The rhyme above only applies for the standard convention of converting direction. When converting from compass- to magnetic direction the **opposite** will apply.

4.5 Direction Reference System

The table below is a summary of the concepts discussed and illustrates the three North references commonly used in aviation and the processes of conversion.

True Direction	Measured clockwise through 360° on the map, using the meridians to identify True north as reference. True direction is used to indicate the flight path of the aircraft on a map.
Variation	Obtained from the isogonals on the map to facilitate conversion between true and magnetic direction. Standard convention is to convert from true- to magnetic direction.
Magnetic Direction	The direction flown on the compass with no errors with reference to magnetic north.

Deviation	Obtained from the compass deviation card in the aircraft to enable conversion between magnetic and compass direction. Standard convention is to convert from magnetic to compass direction.
Compass Direction	The direction steered using the aircraft's compass after correcting for the error induced in the compass by the interaction between the Earth and aircraft's magnetic fields.