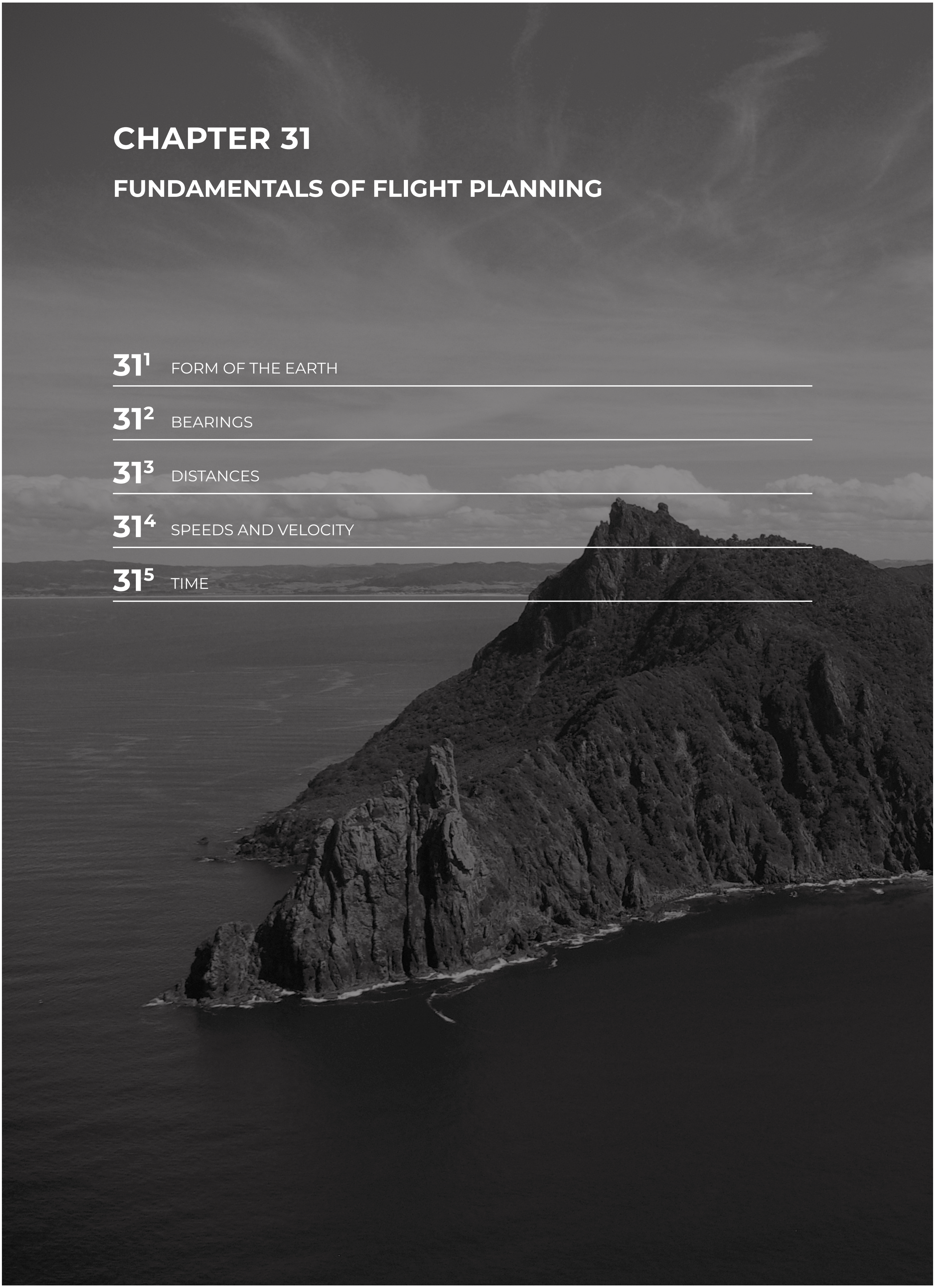

CHAPTER 31

FUNDAMENTALS OF FLIGHT PLANNING

Cartography is an ancient art and science that aims to produce two-dimensional charts representing our spherical Earth. Before we even start to plan a flight, it is essential that we have an appreciation of how this representation occurs, how compasses work and the bearing types.

31[1]

FORM OF THE EARTH

What is the shape of the Earth?

The shape of the Earth is oblate spheroid – not a true sphere, as the distance between the two poles is slightly less than the diameter at the equatorial axis, which gives it somewhat of a squashed appearance.

What are the true poles of the Earth?

The northernmost geographic point on Earth is known as true north. The southernmost point on Earth is known as true south. The Earth's axis is located between these two points and is tilted (*Figure 252*). The Earth rotates in an anti-clockwise direction when viewed from above and clockwise when viewed from below.

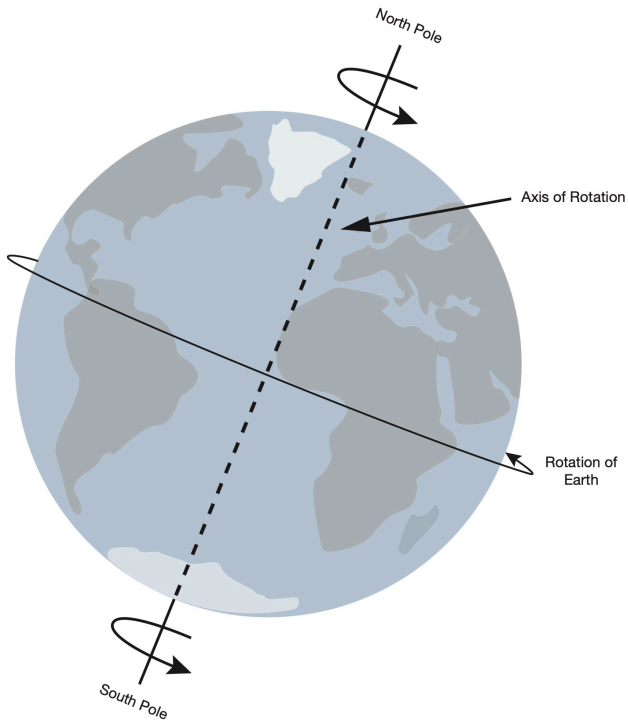

Figure 252. Diagram to show the axis of the Earth and the rotation around the poles.

How do the magnetic and true poles differ?

The Earth's molten core produces an electromagnetic field or flux around the Earth (*Figure 253*). The Earth's magnetic axis is between the magnetic poles – magnetic north and south respectively. These positions do not match the geographic poles (true north and south). Rather, they differ by hundreds of miles at the North Pole and over a thousand miles at the South Pole!

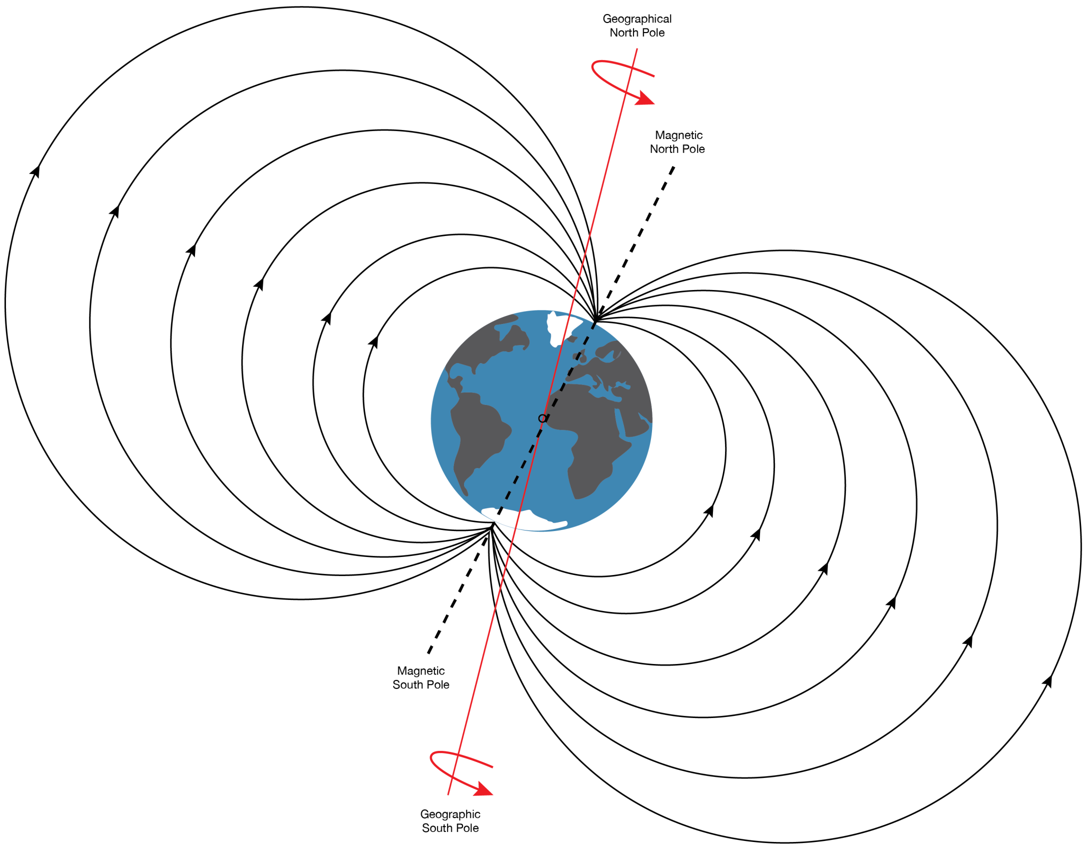

Figure 253. Diagram to show Earth's magnetic poles with flux fields and the relationship to the geographic poles.

The positions of the magnetic poles also move over time. This is due to changes in the molten Earth's core, which causes shifting of the magnetic field/flux axis. As the axis changes, it causes the magnetic poles to revolve around the true poles over hundreds of years.

Compasses line up with the magnetic field/flux axis, with one end aligning with magnetic north and the other with magnetic south. So, if you are a polar adventurer looking to navigate your way to the poles, it is probably best not to aimlessly follow the direction of your compass as it will point towards the magnetic poles rather than your intended destination, being the true poles. This also means that when we use our compass for navigation purposes, we need to consider the **magnetic variation** – the difference between a magnetic bearing and a true (geographic) bearing.

Useful definitions

True North – This is the northern geographical pole of the Earth.

Magnetic North – This is the northern magnetic pole of the Earth, which rotates around the true North Pole. The difference between true north and magnetic north is known as variation.

True Direction – The direction in degrees from one point to another, with true north as 000° (T°).

Magnetic Direction – The direction in degrees from one point to another, with magnetic north as 000° (M°).

How can a position on Earth be described?

Once the Earth's curved surface is projected onto the flat chart surface, it is divided into a reference grid. Locations can be described as either north or south of the reference datum of the **equator** and east or west of the reference **prime meridian** (*Figure 254*).

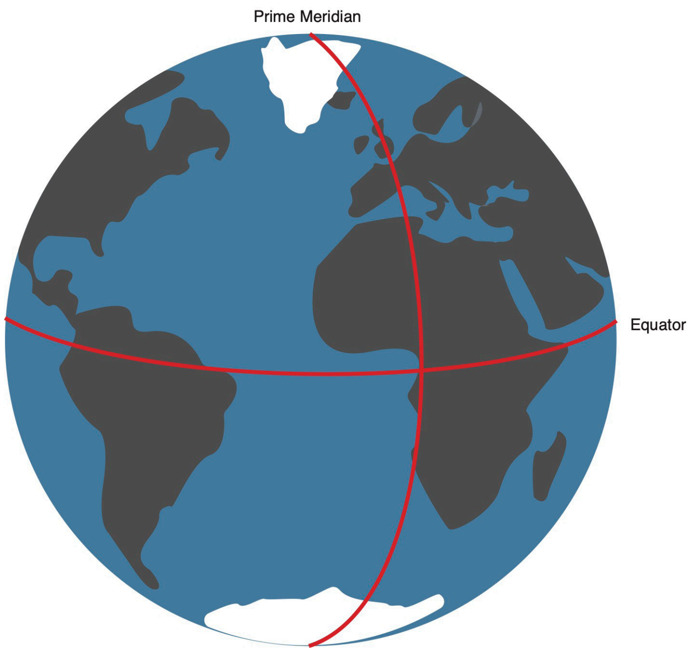

Figure 254. Diagram showing the equator and prime meridian datum lines.

Equator

This line around the Earth is perpendicular to the polar axis and bisects the Earth equally into two hemispheres as it passes around the Earth's centre. It is regarded as 000° latitude.

Prime meridian

This is the line around the Earth which is parallel to the polar axis and bisects the Earth equally into two spheres as it passes around the Earth's centre. Greenwich, London, UK is used as the datum position for the prime meridian for historical reasons and is regarded as 000º longitude.

Parallels of latitude

Parallels of latitude are parallel to the equator (i.e. they run east/west) and can be used to reference north/south of a position. The equator is 000º and the North Pole and South Pole are 090ºN and 090ºS, respectively.

Meridians of longitude

Meridians of longitude travel in a north/south direction and are almost parallel to the prime meridian (not quite, due to the shape of the Earth). The prime meridian is regarded as 000º and meridians running up to 180ºE and 180ºW.

Meridians of longitude are like slices of a mandarin (sort of).

Coordinates

- Coordinates are a standardised method of annotating a position on Earth as a series of digits. The first half represents the degrees, minutes and seconds latitude (east/west) of a position and the second half describes the degrees, minutes, seconds longitude (north/south) of a position. As such, the coordinates will generally follow one of two standardised annotations: DDºMM.MM' (Degrees Minutes Decimal) or DDºMM'SS" (Degrees Minutes Seconds):
- **Degrees (°) –** Ranges from 0 to 90º latitude and 0 to 180º longitude.
- **Minutes of an arc (') –** Each degree can be divided into 60 minutes of an arc. A minute, therefore, represents 1/60 of a degree and enables greater accuracy in the coordinates.
- **Seconds of an arc (") –** Each minute is divided into 60 seconds of a minute. A second, therefore, represents 1/60 of a minute and further increases accuracy in the coordinates. Alternatively, a decimal of minutes can be used (MM.MM') which is commonly used in GNSS navigation units.
- **Direction –** Latitude will be marked as degrees N/S (north/south of the equator) and longitude marked as degrees E/W (east/west of the prime meridian).

31^2

BEARINGS

How is the 360-degree direction method used?

When a circle is divided into 360-degree segments (*Figure 255*), it can be used to indicate direction. 000° indicates north, 090° indicates east, 180 ° indicates south and 270 ° indicates west and are known as the **cardinal directions** of the Earth. The **inter-cardinal directions** of the Earth are northeast (045 °), southeast (135 °), southwest (225 °) and northwest (315 °).

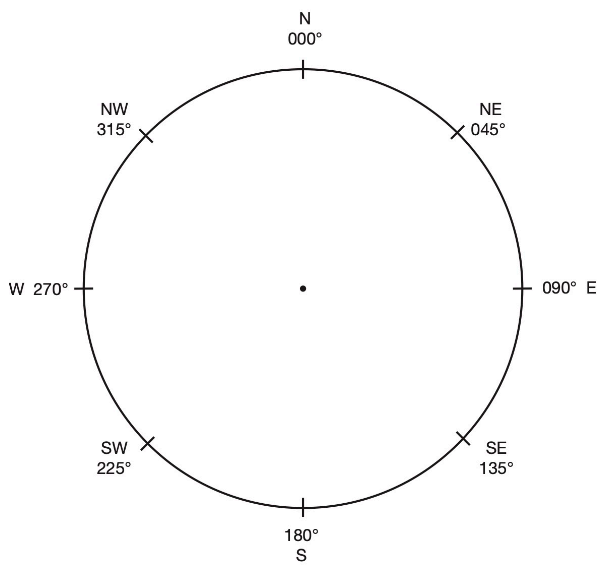

Figure 255. Diagram showing directional degrees with the cardinal and inter-cardinal directions.

What is a bearing?

A bearing is a direction (in degrees, °) from one point to another. It can be a true bearing, a magnetic bearing or a compass bearing. These are described as:

- **True bearing (T°) –** This is the bearing from one point to another using true north as the datum (000°). A true bearing is obtained straight from a visual navigation chart.
- **Magnetic bearing (M°) –** This is the bearing from one point to another using magnetic north as the datum (000°). The magnetic bearing differs from a true bearing by the magnetic variation (see below).
- **Compass Bearing –** This is the bearing from one point to another using compass north datum (000°). The compass bearing is the same as the magnetic bearing but with a compass deviation applied (see below).

What is magnetic variation?

Magnetic variation is the difference between a true bearing and a magnetic bearing. The reasons for this are the asymmetrical nature of the Earth's magnetic flux and the movement of the Earth's molten core that cause it to change over time.

- It is more accurately referred to as magnetic declination but is commonly called variation. Variation occurs due to the difference in position of true north and magnetic north. Magnetic north will differ by a certain number of degrees East or West of true north, depending on where you are on Earth and the year.

How can magnetic variation be calculated?

The magnetic variation is printed on every chart as an east or west variation in degrees (*Figure 256)*). The actual variation needs to be calculated to account for changes over time and location from the printed chart information.

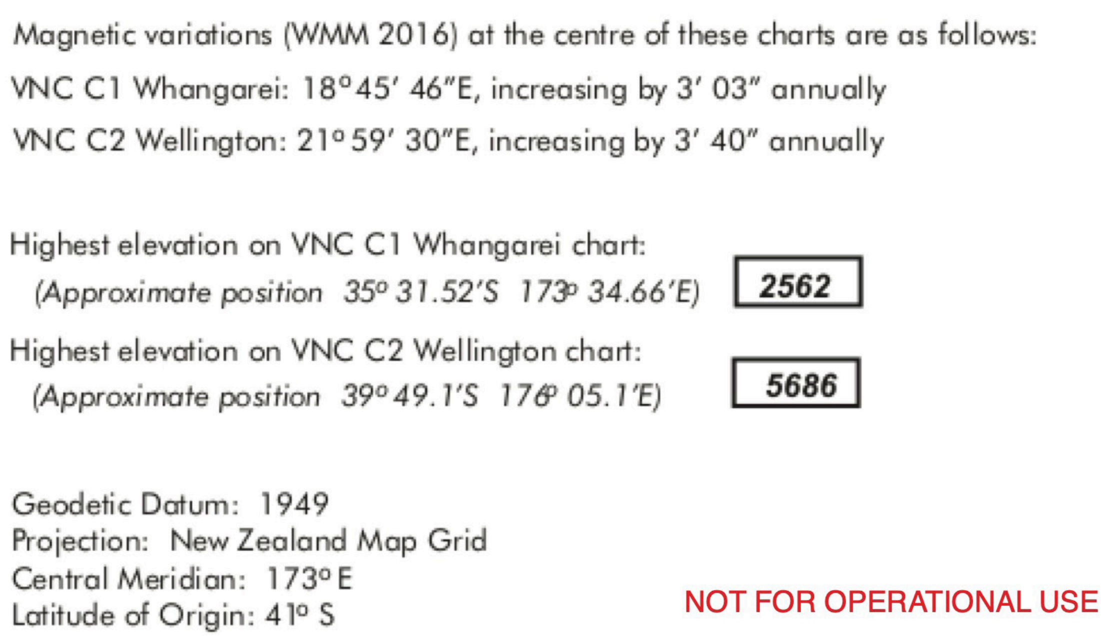

Figure 256. Aeronautical chart section showing magnetic variation. ©Civil Aviation Authority of New Zealand, supplied by Aeropath Limited.

Accounting for change over time

As shown in *Figure 256,* magnetic variation is stated in degrees and direction (east/west) with the "geodetic datum" year and a rate of change. To calculate the current magnetic variation, the difference in years between the datum year to the chart year (current year) is multiplied by the rate of change published on the chart.

Accounting for change by location

Each chart displays the magnetic variation for the areas it represents. Places with the same magnetic variation are regarded as being on an **isogonal** line. An agonic line follows locations with no magnetic variation – for instance, the magnetic and true bearings are the same. The closest agonic line currently runs near Perth, Western Australia (*Figure 257*).

- In New Zealand, variation ranges between 18° east and 24° east, depending on where in the country you are and generally decreases as you travel North. This means that the magnetic bearing is 18° to 24° East of true north, i.e., magnetic bearings will be lower than true bearings. Therefore, the variation needs to be subtracted from a true bearing to convert it to a magnetic bearing. Conversely, to convert the magnetic bearing to a true bearing, the variation must be added to the magnetic bearing.

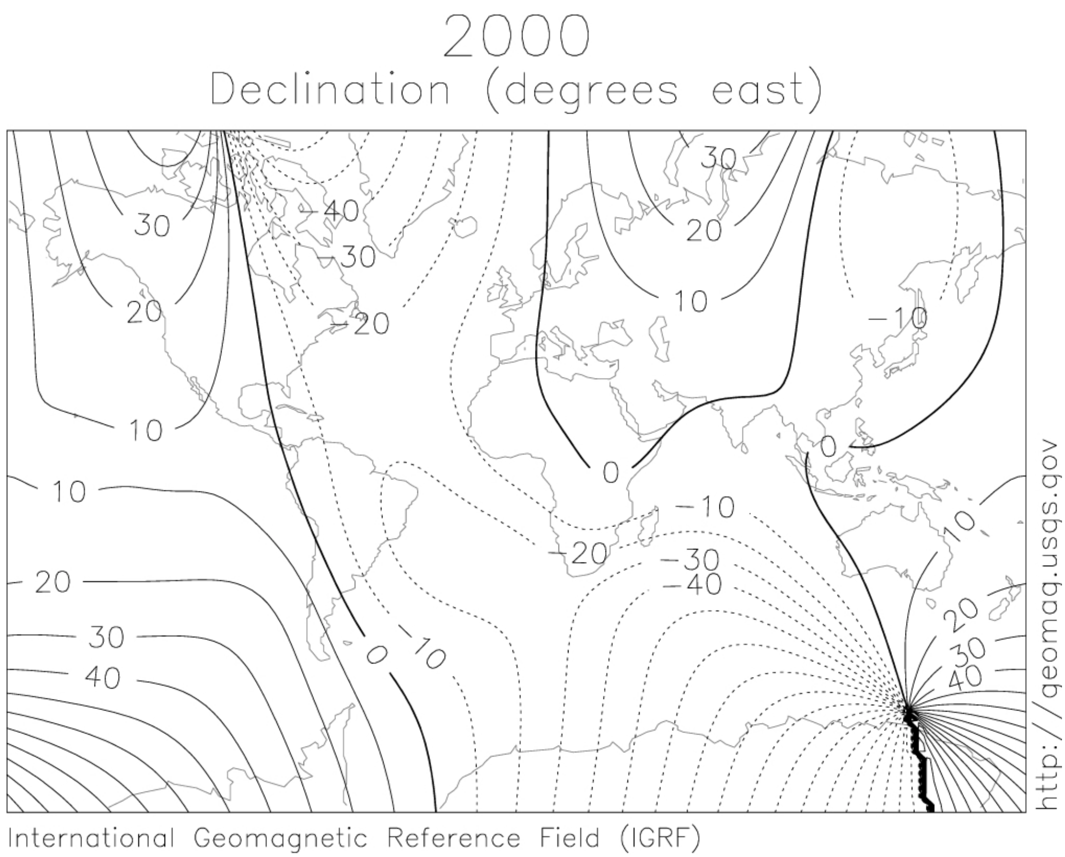

Figure 257. Magnetic variation/declination varies throughout the World but in a non-linear fashion as shown in the diagram (attributed to United States Geological Survey through https://commons.wikimedia.org/wiki/File:IGRF_2000_magnetic_declination.gif)

To remember the conversion:
If variation is east, magnetic is least
If variation is west, magnetic is best (greater)

How does compass bearing differ from magnetic bearing?

- A compass will align with magnetic north. However, as the compass needle can be deflected by interference with other magnetic fields, e.g., around metallic objects it shows a compass heading. The deflection caused by this interference is known as compass deviation. Thus, **compass deviation** is the difference in bearing (degrees) between magnetic north (magnetic heading) and compass north (compass heading).

The compass deviation is measured in each individual aircraft compass (*Figure 258*). When it is measured a compass deviation card that is produced and displayed within the aircraft.

The compass deviation must be applied to magnetic heading to find the compass heading to follow during a flight, e.g. a compass card will say "For 000° steer 002°".

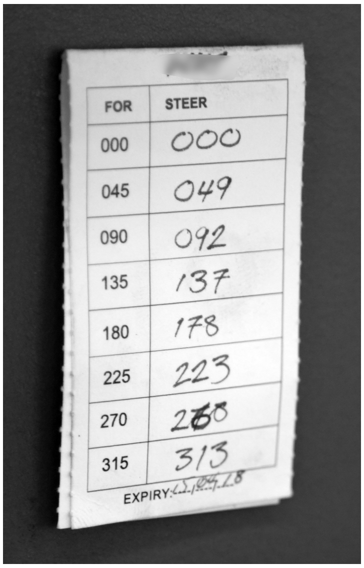

Figure 258. Photograph of compass deviation card in a general aviation aircraft.

What is a relative bearing?

A relative bearing is the bearing of one object to another when the reference 000° line is taken as the nose of the aircraft/direction of travel (as opposed to true north). This is presented in *Figure 259*. Bearings are taken in the same clockwise manner and an approximate relative bearing can be described using the "clock code" method (*see Part 1: Air Law*).

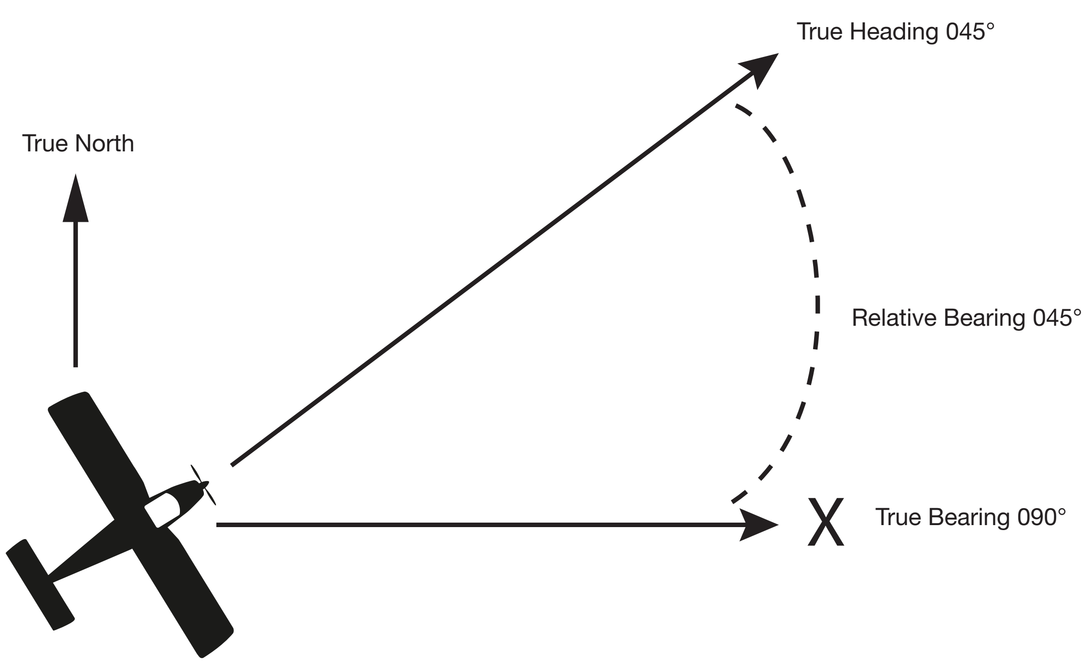

Figure 259. Relative bearing versus true bearing.

How do you calculate the magnetic bearing of an object from a relative bearing?

When airborne, it is easy to measure the relative bearing to any object or location of interest, and it can be helpful to then convert it to a magnetic bearing. The compass deviation card displayed within the aircraft converts a magnetic to a compass bearing. As a result, the opposite is needed to convert a compass to a magnetic bearing.

The magnetic bearing of an object/location equals the aircraft magnetic heading (a magnetic bearing) plus the relative bearing. Remember that the compass goes to a maximum of 360°. Therefore, if this calculation goes above 360°, it needs to be reset at 360° to calculate degrees above 000°.

Therefore, it can be said that:

Magnetic bearing (°) = magnetic heading (°) + relative bearing (°)

If this answer is below 360°, this is the magnetic bearing of your aircraft to the object of interest. If this answer is above 360°, you must subtract 360° from the total to give the magnetic bearing.

Can this be converted into a true bearing?

Yes, it can. To convert a magnetic bearing to a true bearing (*Figure 260, on next page*), the magnetic variation needs to be applied. In New Zealand, the magnetic variation needs to be added to the magnetic bearing as the magnetic variation is to the east, and vice versa for a western magnetic variation.

Plot your route

↓

TRUE BEARING

↓

Apply VARIATION

↓

MAGNETIC BEARING

↓

Apply DEVIATION

↓

COMPASS BEARING

↓

Fly Your Aircraft

Can	**D**ucks	**M**ake	**V**ertical	**T**urns
Compass	**D**eviation	**M**agnetic	**V**ariation	**T**rue

Figure 260. Flow chart showing the conversion of a true bearing to a compass bearing.

31[3]

DISTANCES

What are the different units of distance measurement?

There are many units to measure distance, including:

- **Statute mile –** The statute mile was defined in Imperial Law as 5280 ft and has no use in aviation. However, it is still used for road vehicles in the UK and USA.
- **Nautical mile –** This is equal to 6080ft (6076.1ft exactly) or 1852m and is defined as the length of an arc at the equator, which subtends a one-minute angle at the Earth's centre.
- **Kilometre (km) –** This is an SI unit (see Part 2: Aircraft Technical Knowledge) equal to 1000m.
- **Metre (m) –** This is an SI unit equal to 100cm.
- **Foot (ft) –** 1 foot is equal to 12 inches or 30.5cm.

How do you convert between different distance measures?

Regarding standard distance measures, the nautical mile is the longest, followed by the statute mile, with kilometres being the shortest. *Figure 261* shows the mathematical conversion ratios between different measures of distance.

		TO		
		NAUTICAL MILE	STATUTE MILE	KILOMETRE
FROM	NAUTICAL MILE	-	1.15	1.85
	STATUTE MILE	0.87	-	1.61
	KILOMETRE	0.54	0.62	-

Figure 261. Table to show the conversion ratios of common distance measures.

31[4]

SPEEDS AND VELOCITY

What is the difference between speed and velocity?

Velocity is a vector quantity and thus has both magnitude (an amount) and direction. In contrast, speed has only magnitude. However, both measure how fast an object is moving.

What is the unit used to measure speed in general aviation?

The **knot (kt)** is commonly used, where 1 knot is equal to travelling 1 nautical mile per hour.

What are the different types of speeds that can be measured in aviation?

Various speeds are used in aviation for different purposes (see *Part 3: Aircraft Technical Knowledge)*. The typical speeds referred to are:

- **Ground speed (GS) –** This is the speed (knots) at which an aircraft travels over the Earth's surface. This will be affected by the strength and direction of the wind.
- **Indicated airspeed (IAS) –** This is the speed (knots) at which an aircraft travels through the air, as shown by an airspeed indicator. It is not affected by wind strength and direction, and is effectively a measure of air pressure experienced by the aircraft as it moves through the air.
- **True Airspeed (TAS) –** This is the indicated airspeed (knots) corrected for air density and temperature. As the IAS utilises the static and dynamic pressure gauges calibrated for ISA conditions, any deviation from ISA will lead to an inaccurate reading. For example, if air density is reduced (as occurs with an increase in altitude or temperature), then the indicated airspeed will under-read, meaning the true airspeed is higher.
- **Calibrated airspeed (CAS) –** This is the airspeed (knots) when the IAS is corrected for installation instrument and air pressure errors. It is generally not relevant for general aviation, and the CAS is regarded as equal to the IAS.

31[5]

TIME

How are date and time represented in aviation?

It is generally presented as a six-figure date/time group. It contains the date of the month (2 figures) followed by the time (4 figures) – for instance, 1:30 pm on 7th March is 071330 (the month is not annotated).

What are the commonly used reference time zones in New Zealand?

The commonly used reference times are:

- **Coordinated Universal Time (UTC) –** UTC is the reference time zone used globally and was previously regarded as Greenwich Mean Time (GMT). This is referred to as time zone Zulu. It is used globally in aviation, particularly for meteorological reports and Search and Rescue Times (SARTIMEs). It is interesting to note the story behind the nomenclature of UTC: UTC was a compromise between the English "Coordinated Universal Time" (CUT) and the French "Temps Universel Coordonné" (TUC), so it didn't favour one language over another!
- **Standard Time (NZST) –** New Zealand Standard Time is the time zone used for the whole of New Zealand (and is 12 hours ahead of UTC. To convert NZST to UTC, subtract 12 hours (which means it may be the previous day).
- **Daylight Time (NZDT) –** Clocks go forward for "daylight saving" in New Zealand between the first Sunday of September to the first Sunday of April, causing New Zealand to be 13 hours ahead of UTC. The AIP publishes the dates in each year that this occurs. To convert from NZDT to UTC, subtract 13 hours from the time (which also may be the previous day)