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1. True, Magnetic & Compass Direction

Three Reference Datums for Direction

Datum	Reference	Suffix	Source
True	Geographic (True) North Pole	(T)	Maps, INS
Magnetic	Magnetic North Pole	(M)	Magnetic compass (after deviation correction)
Compass	Compass North (aircraft compass)	(C)	Aircraft compass (affected by aircraft magnetism)

True direction is what is shown on maps — the direction to the geographic North Pole. An INS (Inertial Navigation System) finds True direction by detecting Earth's rotation. Most aircraft, however, use magnetic compasses as primary heading references, with INS as a standby or supplement.

The Earth behaves as though a huge, slightly bent bar magnet runs through it, with its magnetic poles approximately (but not exactly) aligned with the True poles. This misalignment creates the need to convert between True, Magnetic, and Compass headings in flight planning.

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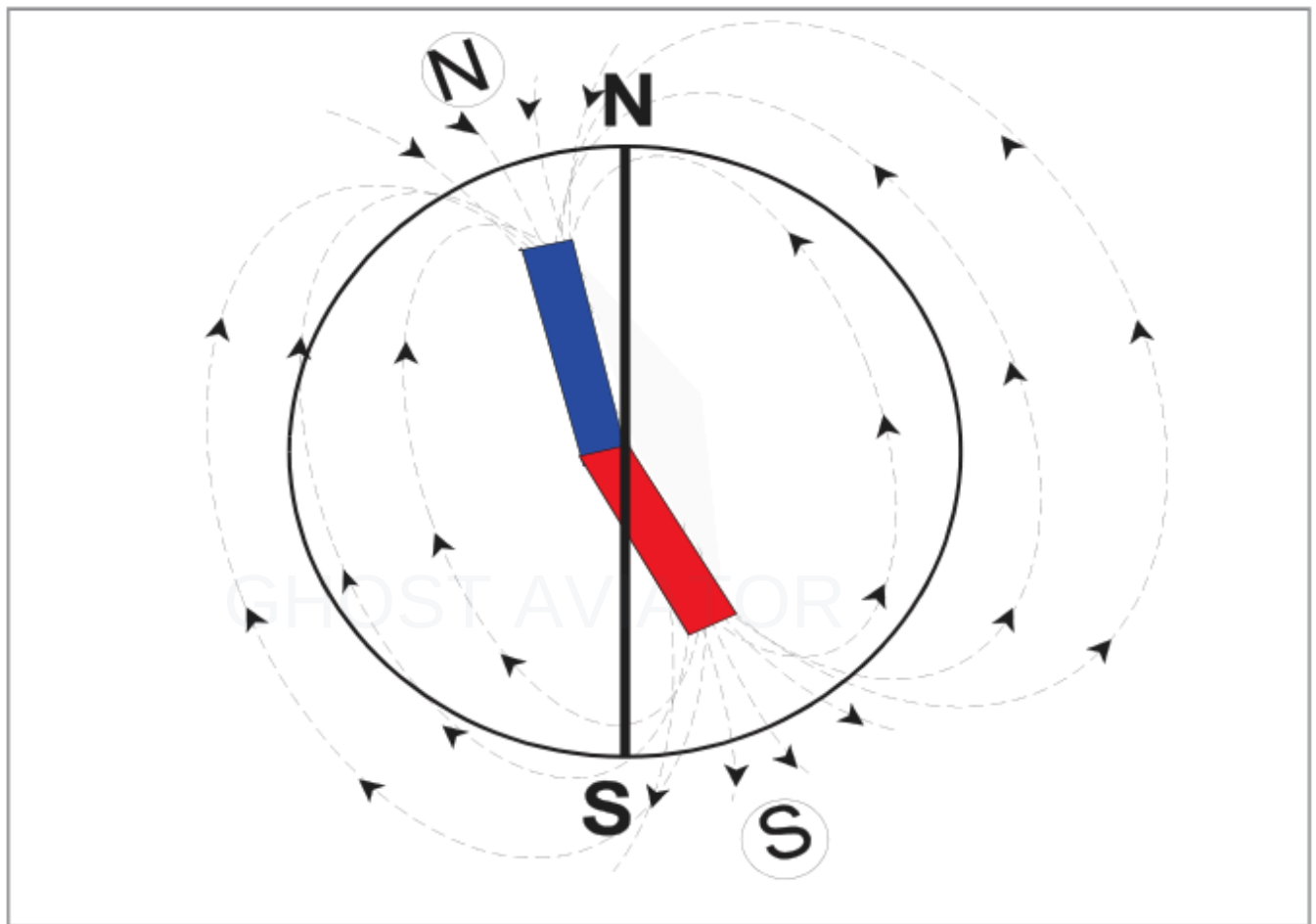


Figure 1 — The Earth's True Poles and Magnetic Poles — not coincident, causing variation

2. Variation — Definition & Observer Geometry

Definition

Variation is the angular difference between the directions of True North and Magnetic North at any point. Measured in degrees East or West from True North. Suffix: **E** or **W**.

- A line joining points of equal variation is an **Isogonal** (shown as a pecked/dashed line on charts).
- The isogon of zero variation is the **Agonic Line**.

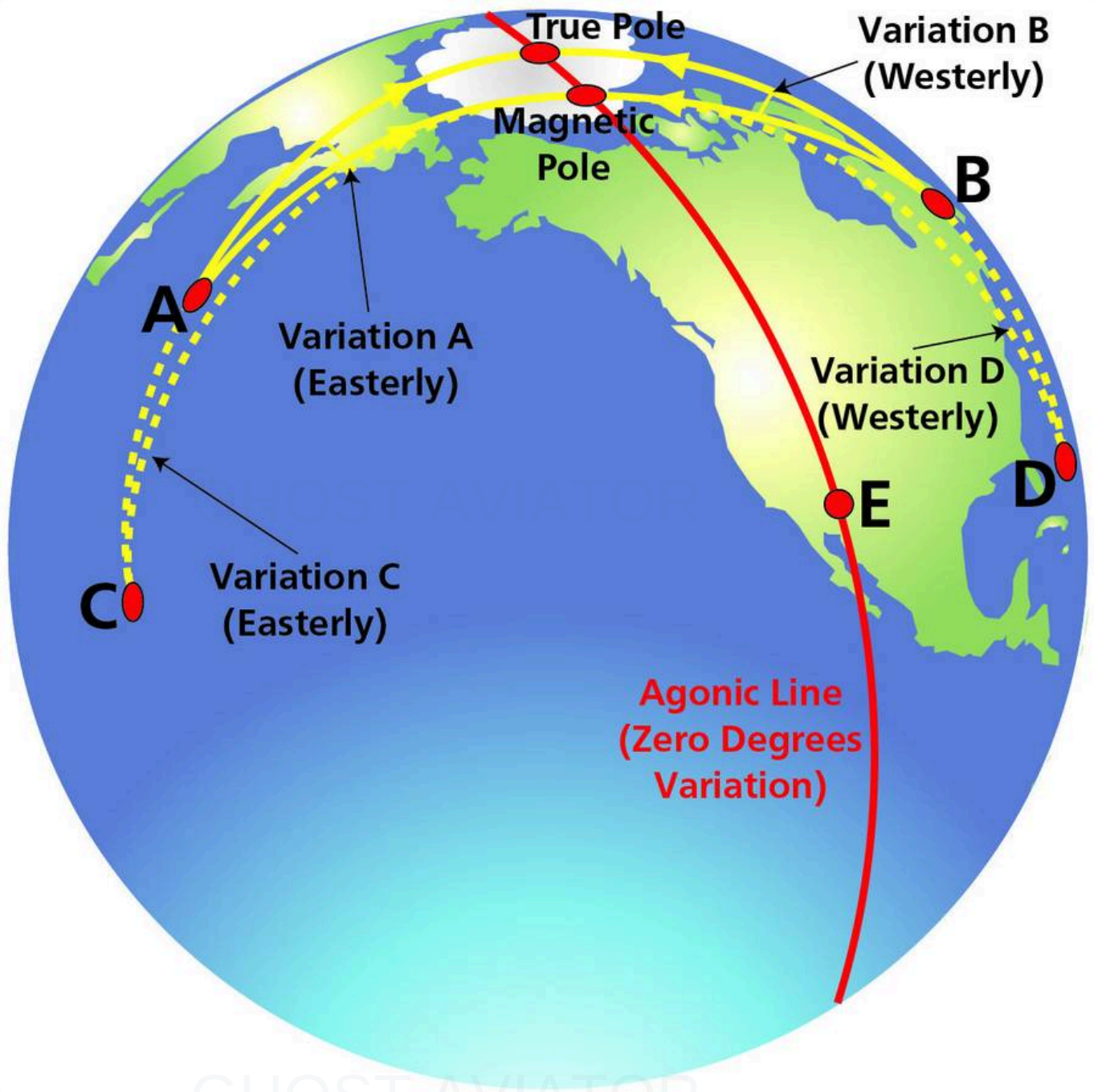


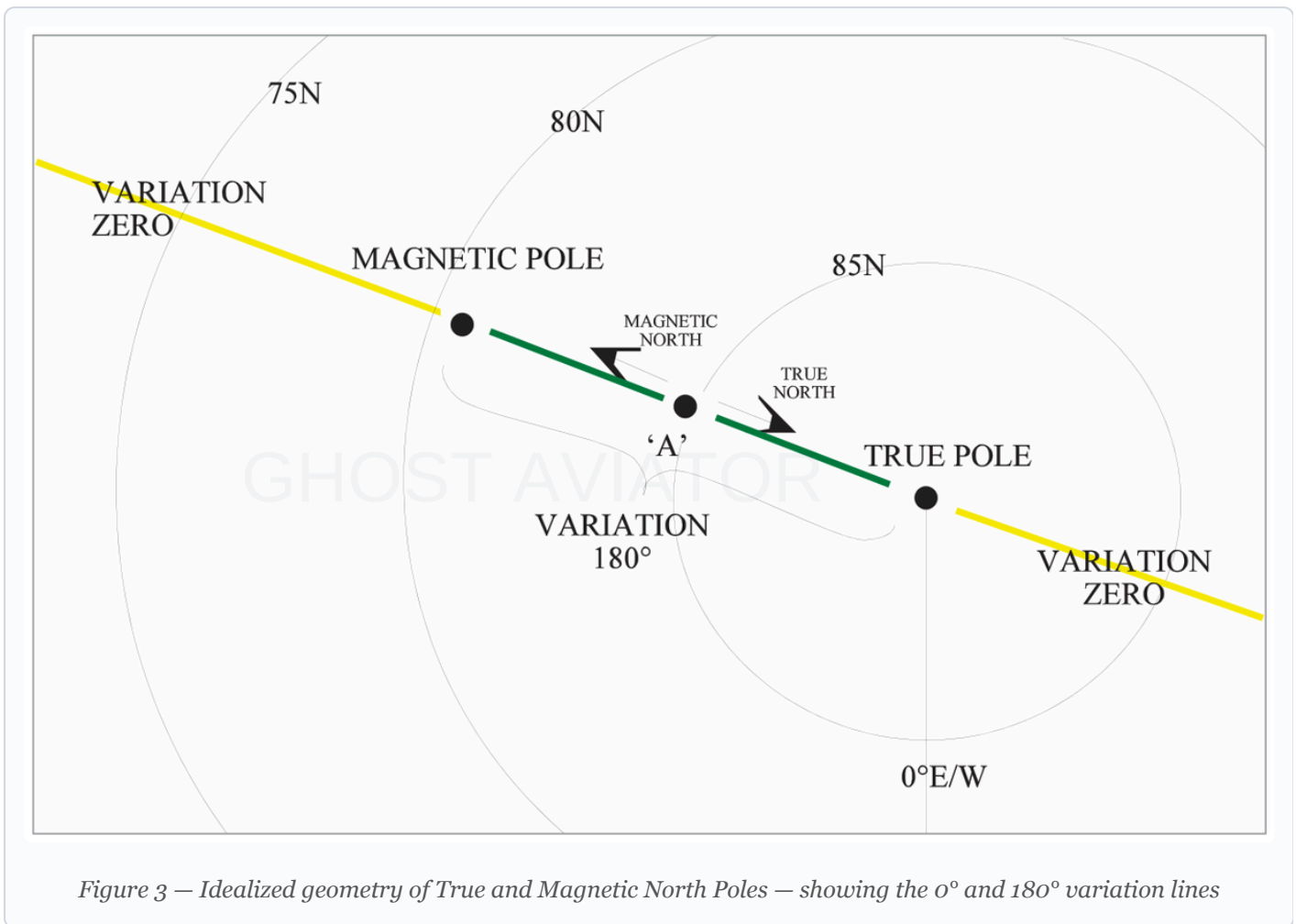
Figure 2 — Idealised model of world variation — how the observer's position geometry determines the direction and magnitude of variation

How Observer Position Determines Variation

The variation at any point depends on the *geometry* of the observer, the True North Pole, and the Magnetic North Pole:

- **Observer A:** Magnetic North Pole is to the *right* of True North → **Easterly variation**
- **Observer B:** Magnetic North Pole is to the *left* of True North → **Westerly variation**
- **Observer C/D:** Further from both poles → **smaller angle** of variation

- **Observer E:** On the Great Circle joining True and Magnetic Poles → **zero variation** (on the Agonic Line)



3. Situation at the Poles — Maximum Variation

For an observer on the arc of the Great Circle *between* the True North Pole and the Magnetic North Pole:

- True North points one way (toward the True Pole)
- The compass needle points in exactly the *opposite* direction (toward the Magnetic Pole)
- The variation at such a point is exactly **180°**

⚠ Maximum Variation = 180°

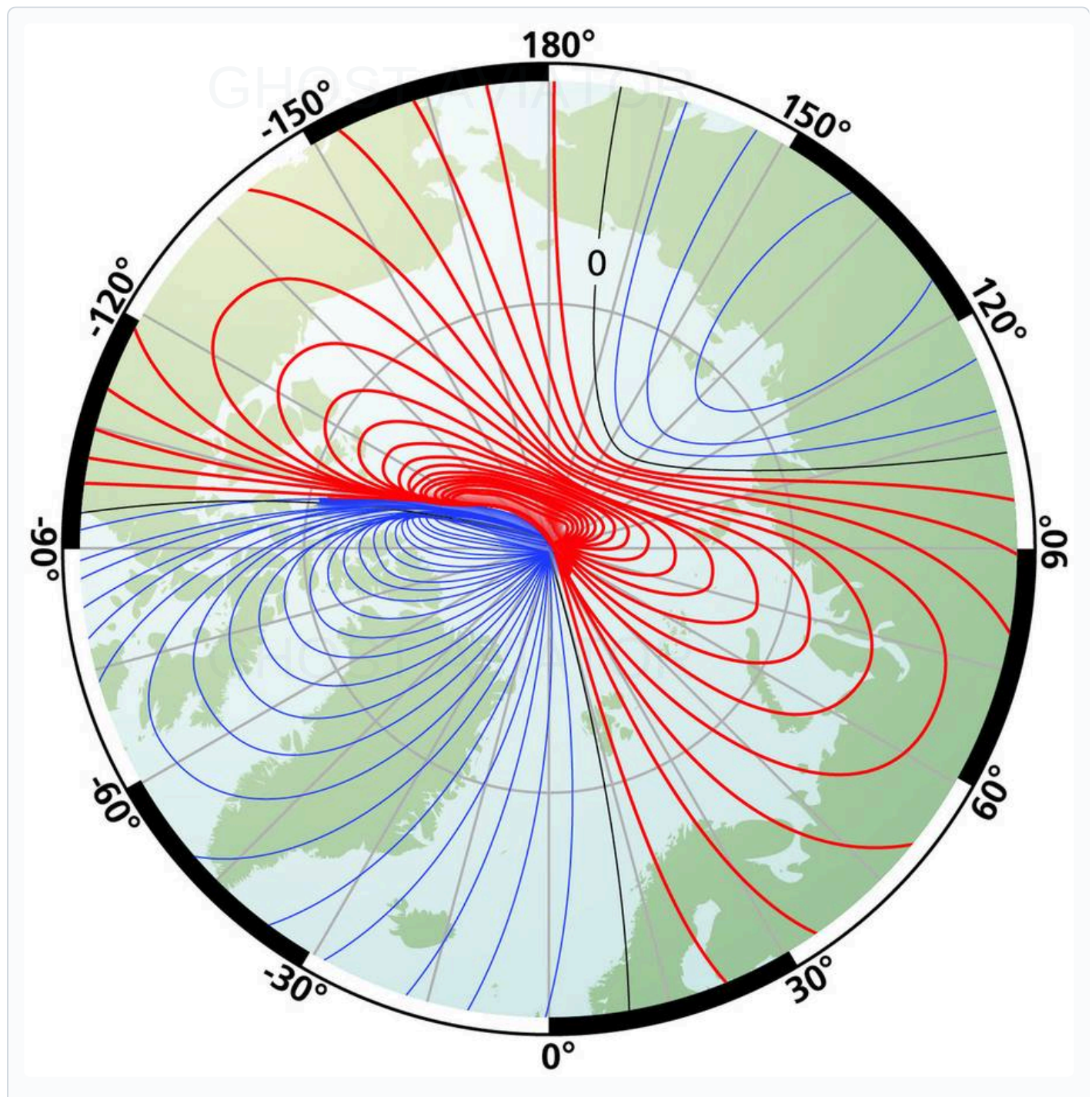
The maximum possible value of variation is **180°** . It occurs between the True and Magnetic Poles. At the True Poles themselves, isogonals converge and variation is indeterminate (all directions are either only North or only South).

4. The Real Variation Map — Isogonals & Agonic Lines

The real magnetic field is more complex than the idealised model — it resembles a *bent* bar magnet. The North Magnetic Pole (NERC 2000 survey) was at approximately **81°N 110°W**; the South Magnetic Pole at approximately **63°S 135°E** — they are *not* antipodal.

There are **two Agonic Lines** (zero-variation lines), both starting from the True North Pole:

- One runs southward through **Western Europe → Stuttgart, Germany → Central Africa → back via North-Central Asia → Australia → South Magnetic Pole**
- The other runs southward through **the USA → South America → True South Pole**



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Figure 4 — Actual variation distribution around the North Pole — isogonals converge on both the True and Magnetic Poles

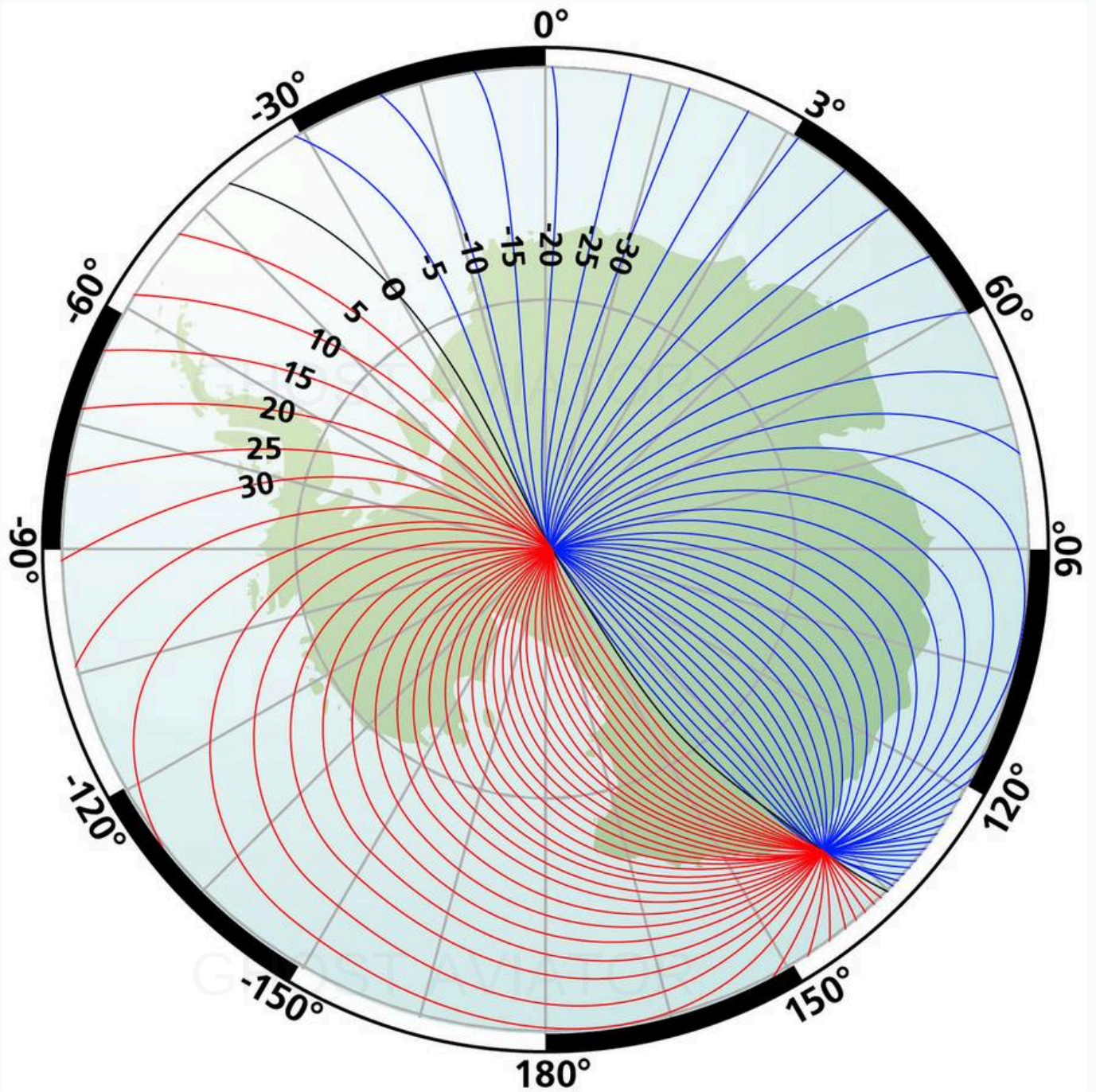


Figure 5 — Actual variation distribution around the South Pole

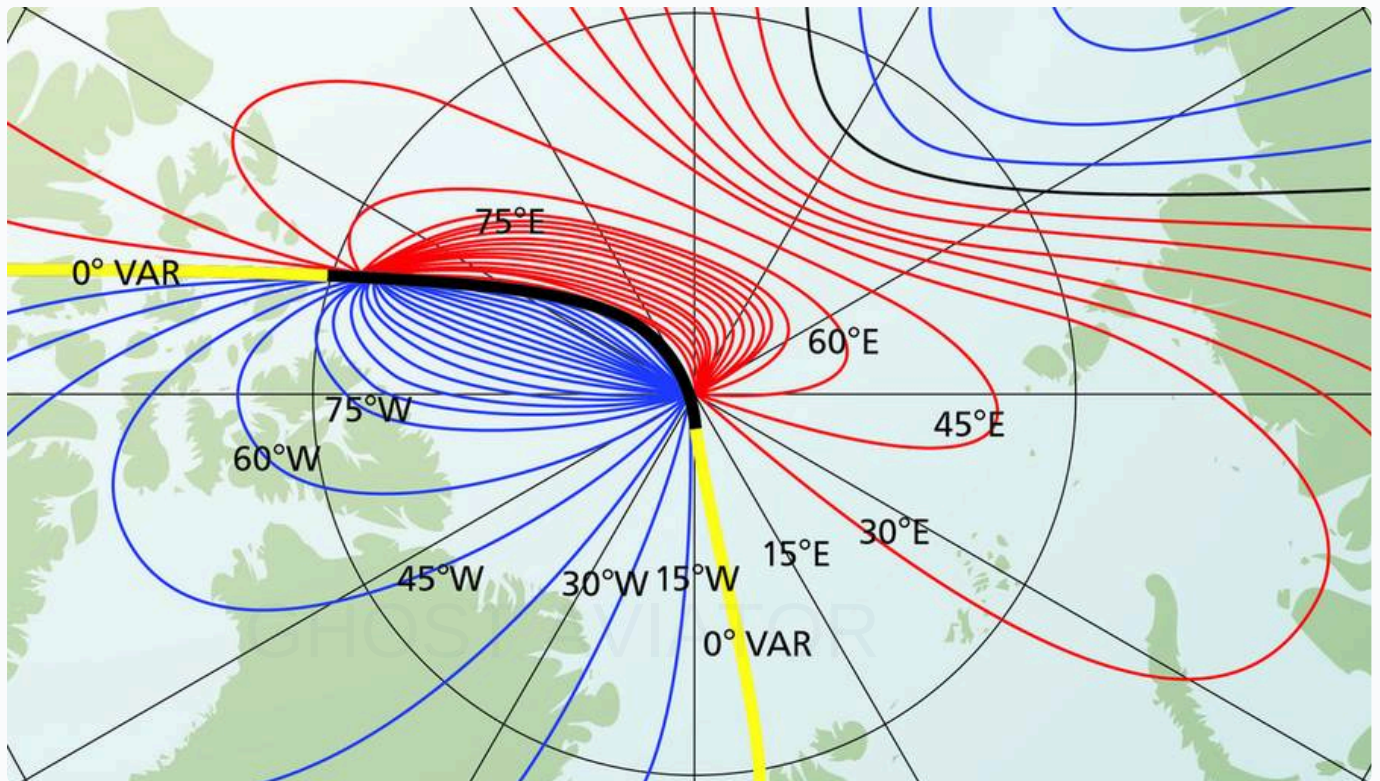


Figure 6 — Variation at the North Pole showing the two Agonic Lines and the 180° variation line between the poles

⚠ Key Exam Facts — Isogonals

- Isogonals converge on **all four poles** — both True (Geographic) AND both Magnetic poles
- Isogonals are NOT the same as magnetic field lines — they show the *difference* between local field direction and True North
- Zero variation (Stuttgart area) does NOT mean no magnetic field — it means Magnetic North = True North at that point

5. Changes in Variation Over Time

Variation at any point changes with time because the Magnetic Poles are moving. There are several overlapping cycles:

Type	Period	Cause	Magnitude
Secular	Long-term drift	Movement of molten magma in the Earth's core; Magnetic Pole moving westward & northward	~1°/9 years at some locations
Annual	~1 year	Earth's orbit round the Sun (sinusoidal)	Small
Diurnal	~1 day	Daily changes in ionosphere height as Earth rotates	Up to ~0.1°
Solar activity	11-year sunspot cycle (unpredictable)	Solar flares hitting the ionosphere — "magnetic storms"	Up to 7° observed
Local anomalies	Constant	Magnetic rock deposits or formations below surface	Variable

Practical Accuracy

It is very difficult to know the instantaneous variation to better than about **±2°**. Over a period of time with careful correction, accuracy of **±0.5°** is achievable. This is why INS (accurate heading from gyros) was a major advance in the 1960s–70s.

6. Updating Isogonals on Charts

For frequently republished radio-navigation charts, isogonals are usually current enough. For topographical maps republished every 5–10 years, pilots may need to update isogonals during flight planning. Charts show the year of origin and the annual change in one of two ways:

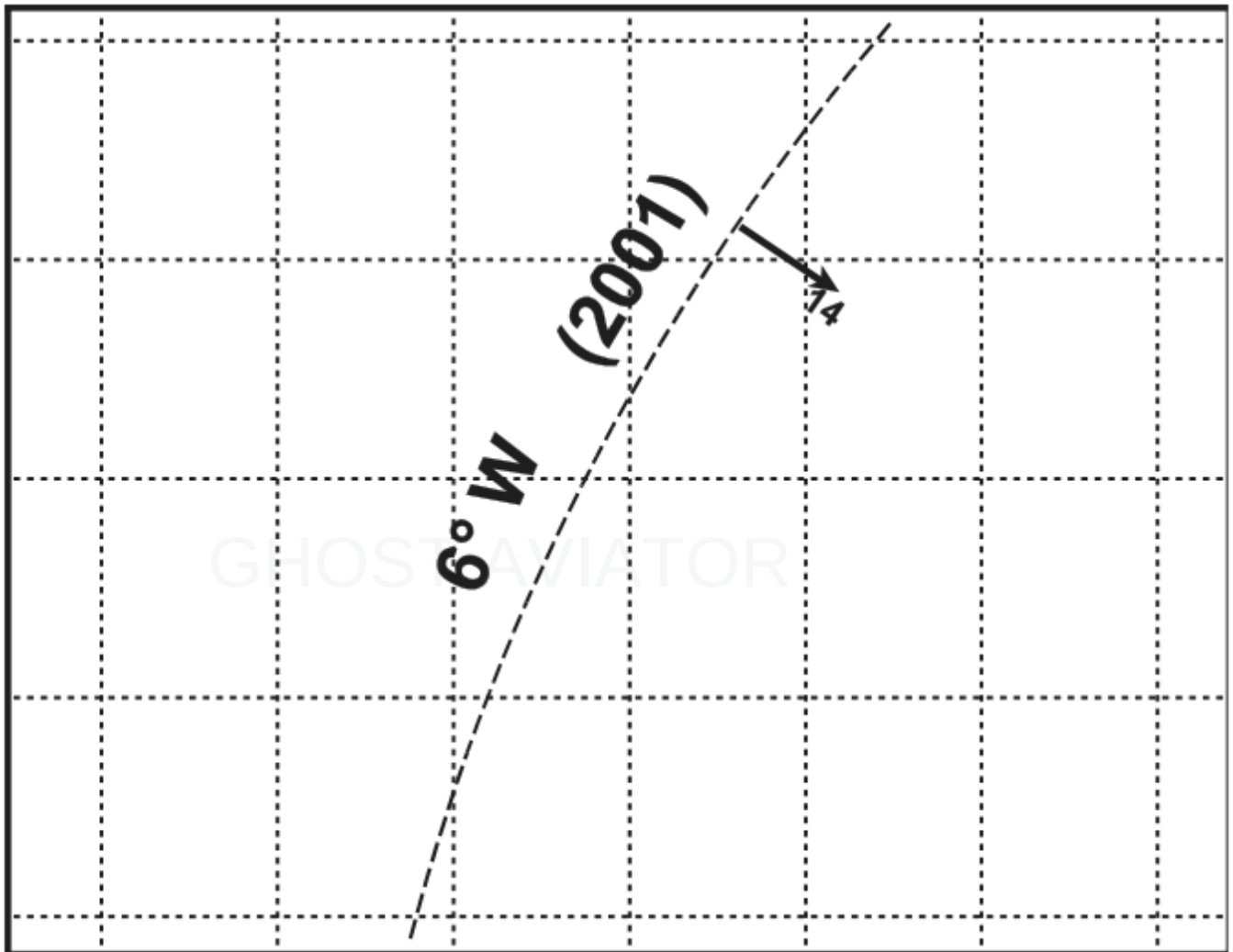


Figure 7 — Isogonal update — annual change shown by an arrow indicating the direction and distance of movement

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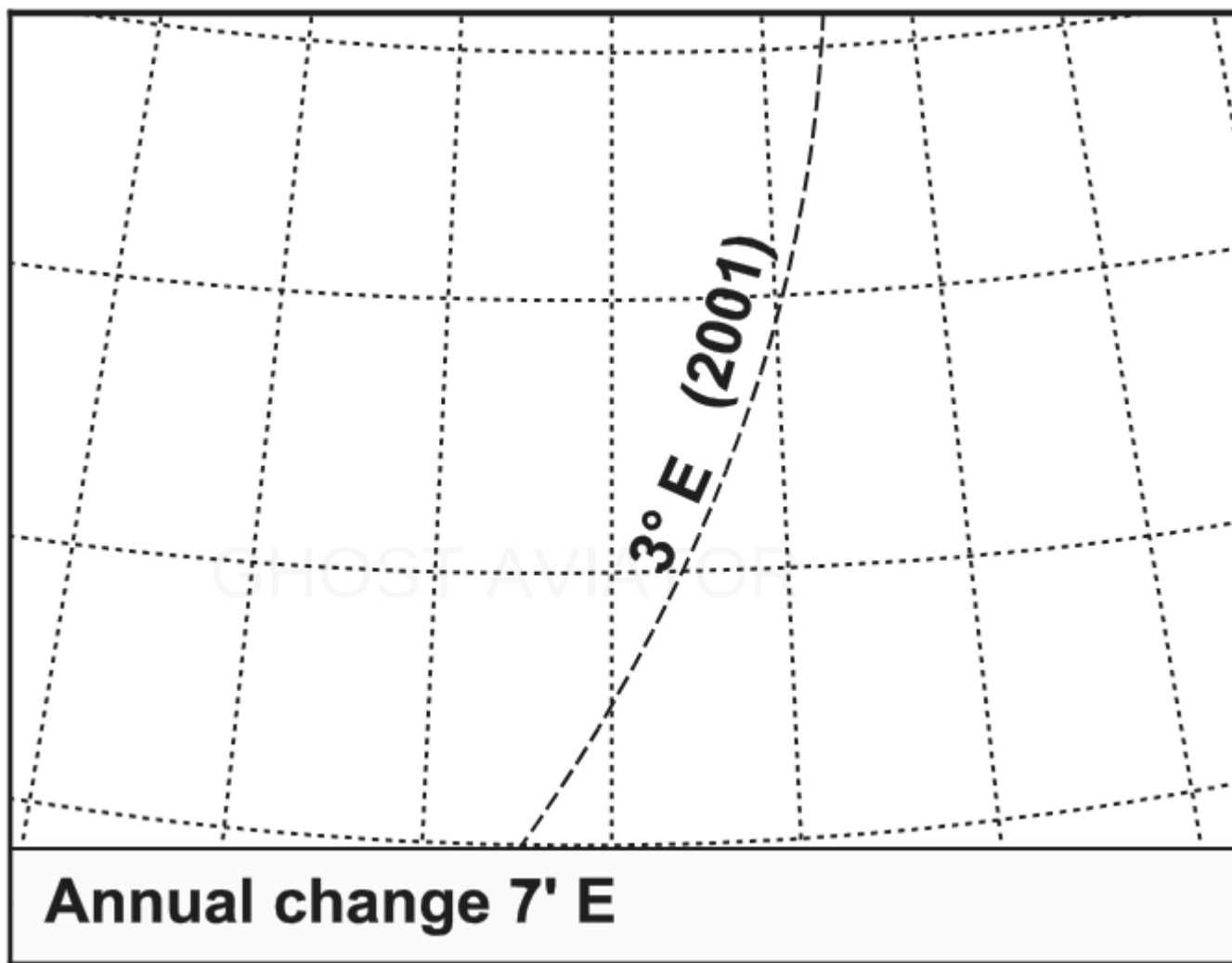


Figure 8 — Isogonal update — annual change shown as a stated value on the chart

7. Magnetic Dip — Angle, H and Z Components

The Earth's magnetic field acts along a **total force vector T**, which is directed into the Earth at an angle to the horizontal. This angle is the **Angle of Dip**.

at positions A, B, and C. The lines of force will make different angles at each location. This angle is known as the **Angle of Dip** and is shown in Figure 3.10.

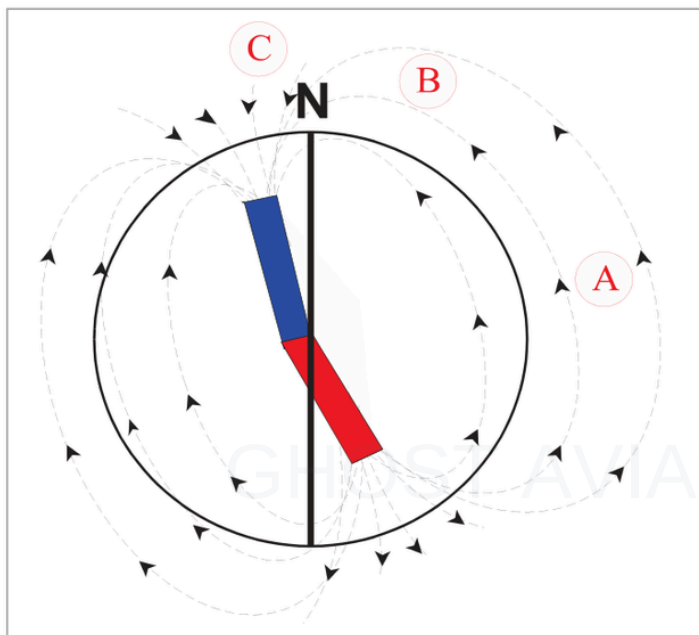


Figure 9 — Lines of magnetic force around the Earth — showing how the dip angle varies from 0° at the magnetic equator to 90° at the magnetic poles

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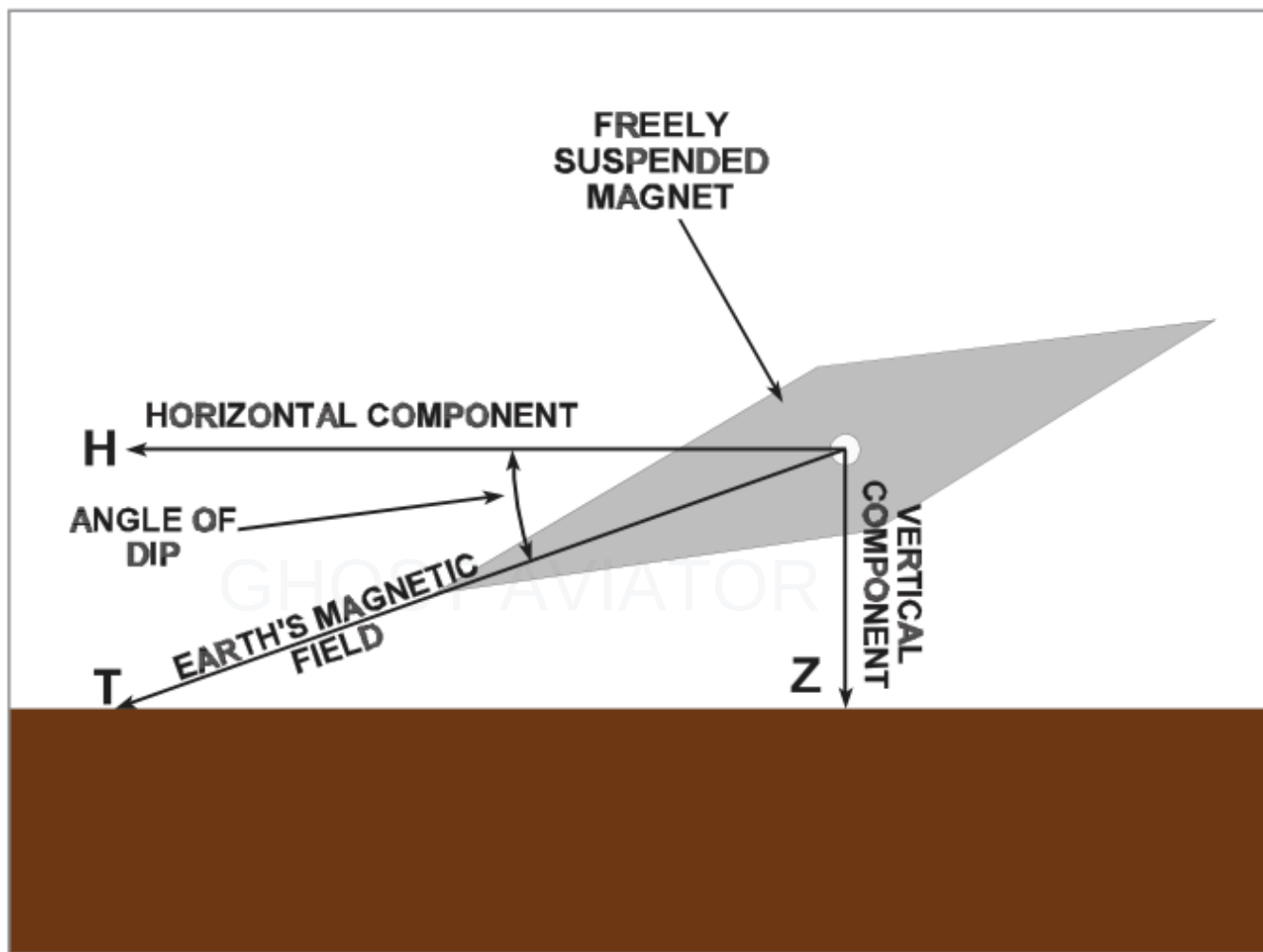


Figure 3.10 The angle of dip

Figure 10 — The Angle of Dip — total force T resolves into horizontal component H (compass-useful) and vertical component Z (useless for direction)

Resolving T into H and Z

Component	Symbol	Direction	Compass use
Total force	T	Along field line (into Earth at dip angle)	—
Horizontal component	H	Horizontal — toward Magnetic North	USEFUL — the directive force
Vertical component	Z	Vertical — into the Earth	USELESS — causes dip errors

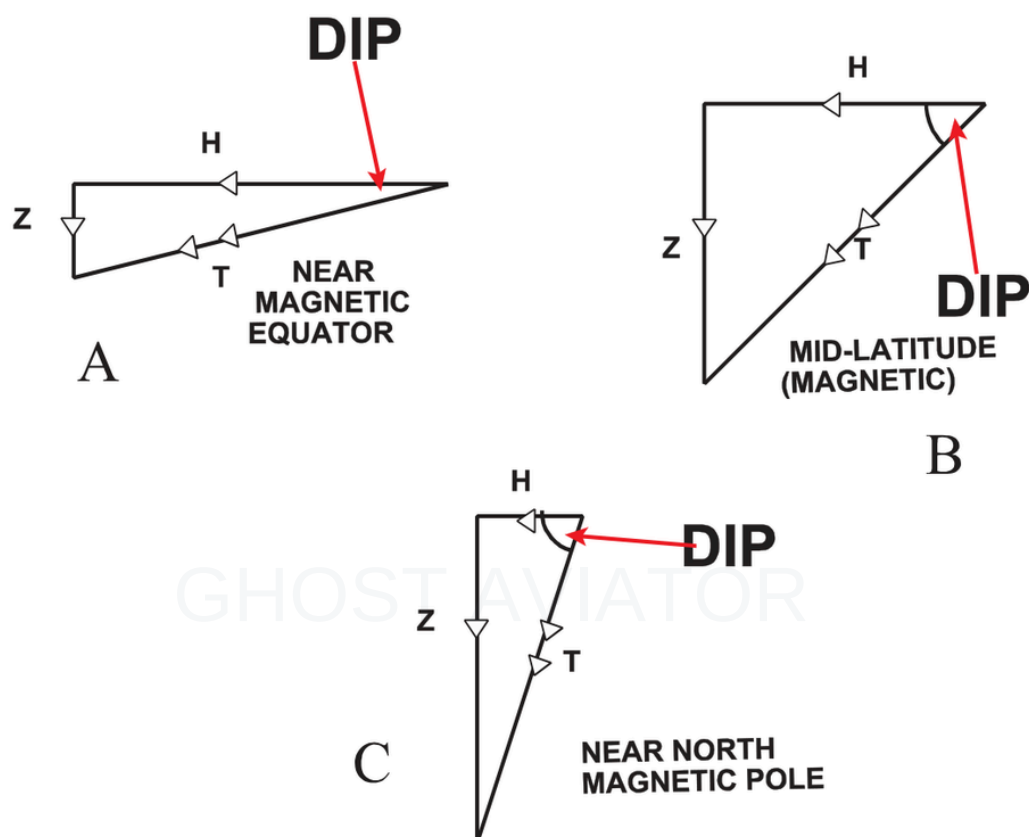


Figure 11 — Effect of latitude on H and Z: at the magnetic equator $H \approx T$ and $Z \approx 0$; at the magnetic poles $H \approx 0$ and $Z \approx T$

Relationship Between Dip and H

- At the **magnetic equator**: Dip = 0° , $H \approx T$ (maximum — compass most effective)
- As latitude increases toward the poles: Dip increases, H decreases, Z increases
- At the **magnetic poles**: Dip = 90° , $H \approx 0$ (compass unreliable)
- At a typical mid-latitude UK location: Dip $\approx 66^\circ$

⚠ Two Problems Caused by Z (Vertical Component)

1. **Compass dip**: Z causes the compass needle to hang down from the horizontal, creating *turning and acceleration errors* (partially corrected by pendulous suspension — residual $\sim 2^\circ$ at a typical mid-latitude location).
2. **Soft-iron deviation increase**: Z induces vertical soft-iron magnetism in the aircraft structure, adding to deviation.

Magnetic field strength is measured in **microteslas (μT)**. H is the directive force. A line joining points of equal magnetic dip is an **Isoclinal**. The isoclinal of zero dip is the **Aclinic Line** (the magnetic equator).

8. The 6 μT Threshold & Compass Reliability

The accepted threshold below which H is too weak to reliably drive a magnetic compass is **6 microteslas (μT)**. Inside the 6 μT zone, compass reliability cannot be guaranteed.

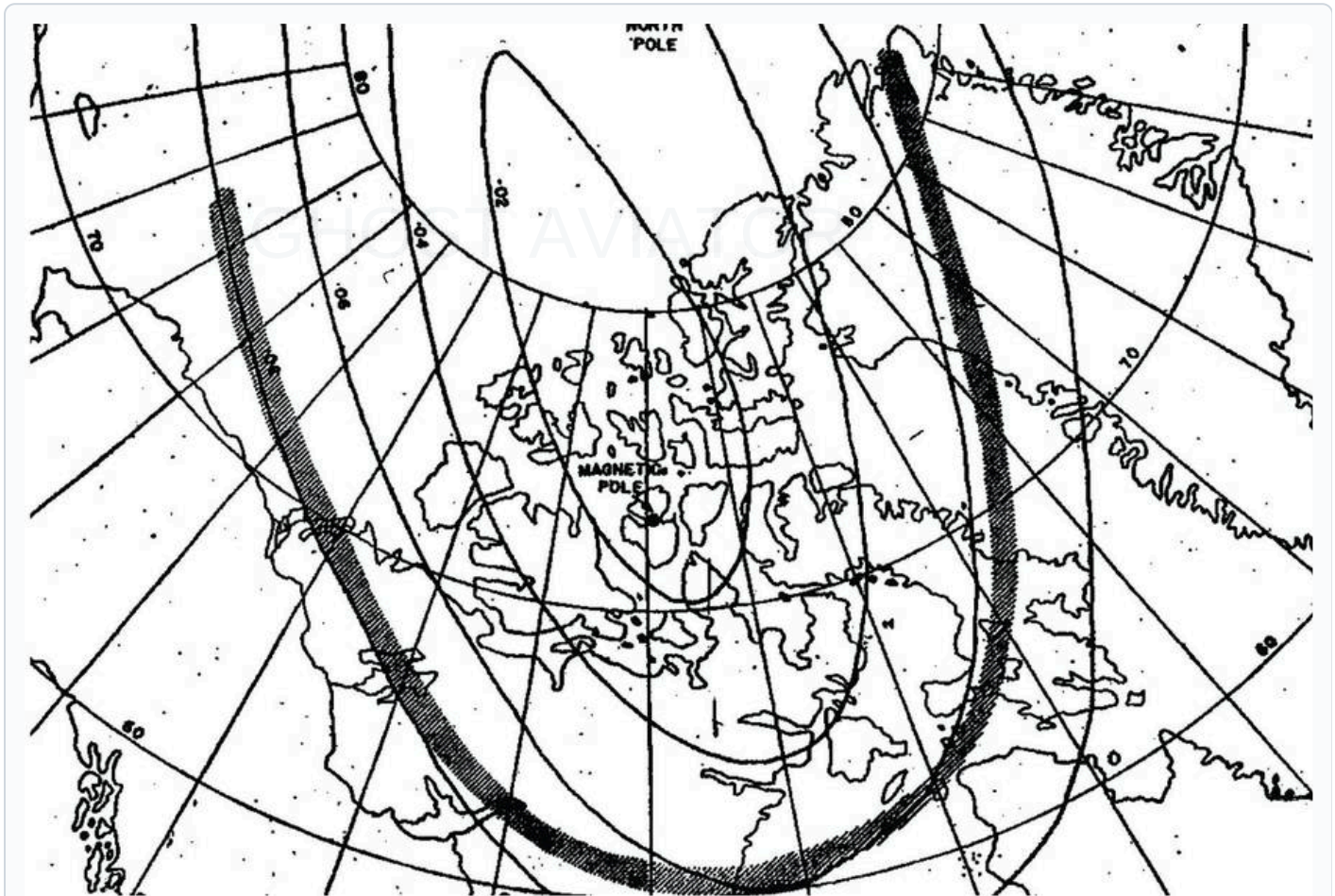
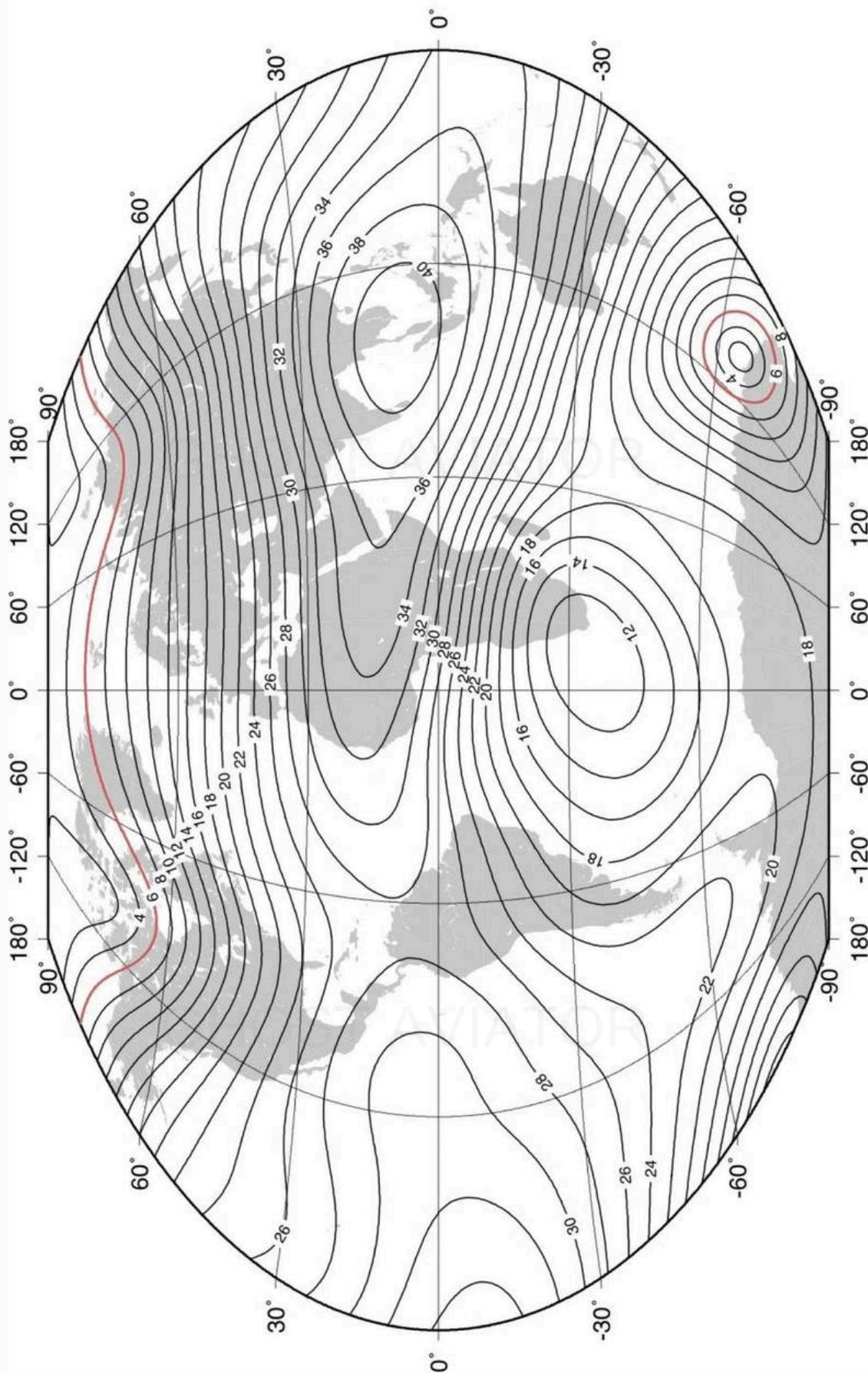
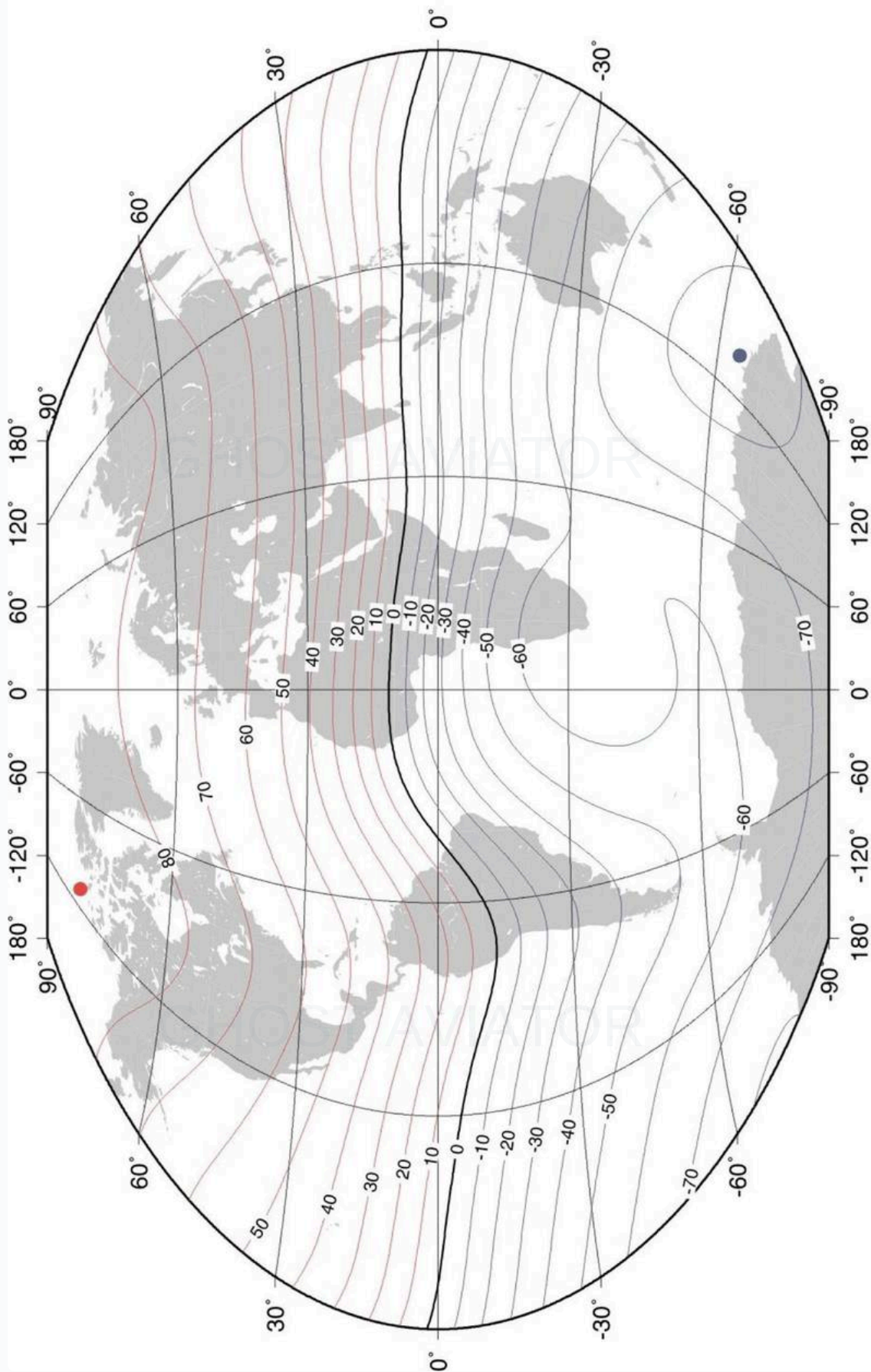


Figure 12 — The 6 μT zone around the North Magnetic Pole (Arctic polar projection, ~1950) — compass unreliable within this region



Horizontal intensity at 2000.0 from the World Magnetic Model (WMM2000). Contour interval is 2 microtesla and projection is Winkel Tripel. The 6 microtesla contour is highlighted - for horizontal intensities less than 6 microtesla the output from some navigation devices may be degraded.

Figure 13 — The 6 μT zones around both the North and South Magnetic Poles (NERC survey, Jan 2000)



Inclination (magnetic dip) at 2000.0 from the World Magnetic Model (WMM2000). Red - positive (down), blue - negative (up), black - zero (dip equator). Contour interval is 10° and projection is Winkel Tripel. This is an example of an isoclinic chart. Locations of dip poles are also shown.

Figure 14 — World dip angle distribution — the magnetic equator (zero dip) and the regions of high dip near the magnetic poles

Exam Tip

The 6 μT zone exists around **BOTH** the North AND South Magnetic Poles. The 6 μT threshold is the notional figure — actual threshold depends on compass design. Maximum dip = **90°** directly over either magnetic pole.

9. Deviation — Definition & Sign Convention

Definition

Deviation is the angle measured at a point between the direction indicated by a compass needle and the direction of Magnetic North. Termed **East** or **West** according to whether Compass North lies to the East or West of Magnetic North.

The aircraft itself contains magnetic influences (metal structures, electrical currents, equipment) which deflect the compass needle from its ideal alignment with Magnetic North. The compass then points to **Compass North** — not Magnetic North.

Sign Convention ($\pm$)

Convention	East deviation	West deviation
Directional suffix	E (e.g. 3°E)	W (e.g. 3°W)
Algebraic sign	+ (positive)	– (negative)

Applied to Compass heading to give Magnetic heading: $\text{Hdg(M)} = \text{Hdg(C)} + \text{Deviation}$ (using algebraic sign).

Equivalently: From Compass to Magnetic, the signs are true — East is +, West is –.

10. Applying Variation & Deviation — CADIZ Rules

North direction may lie either to the West or East of the True North Direction. See [Figure 3.15](#) & [Figure 3.16](#).

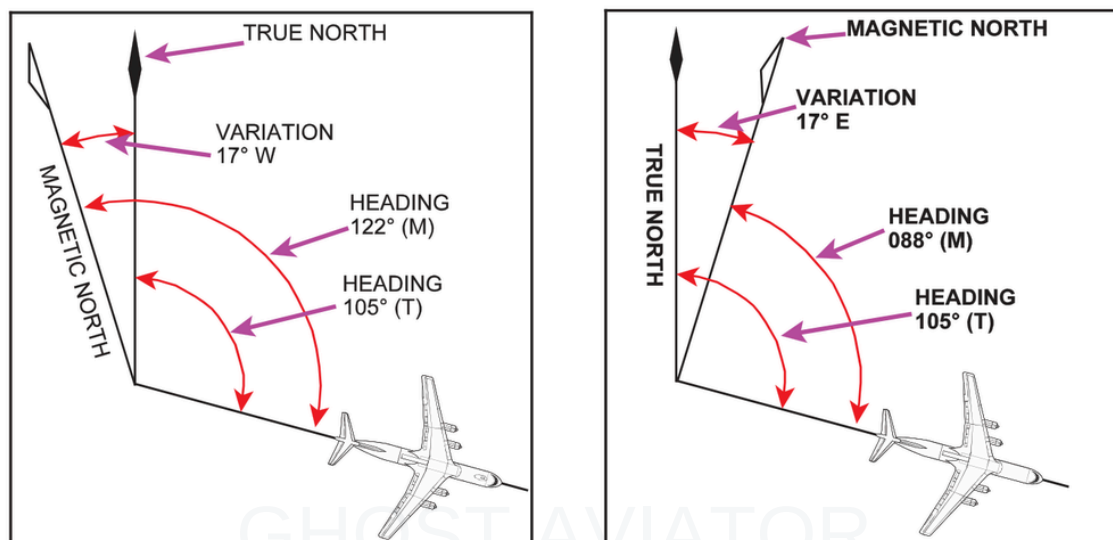


Figure 15 — Westerly Variation (left) and Easterly Variation (right) — how Magnetic North shifts relative to True North, changing the heading readout

Heading True	Variation	Heading Magnetic
105°	17°W	122°

Heading True	Variation	Heading Magnetic
105°	17°E	088°

Figure 16 — Variation application tables — Heading True, Variation, Heading Magnetic for both Westerly and Easterly cases

The CADIZ Chain: C → D → M → V → T

Apply deviation to Compass → get Magnetic; apply variation to Magnetic → get True

VARIATION WEST — MAGNETIC BEST (Magnetic heading > True heading)

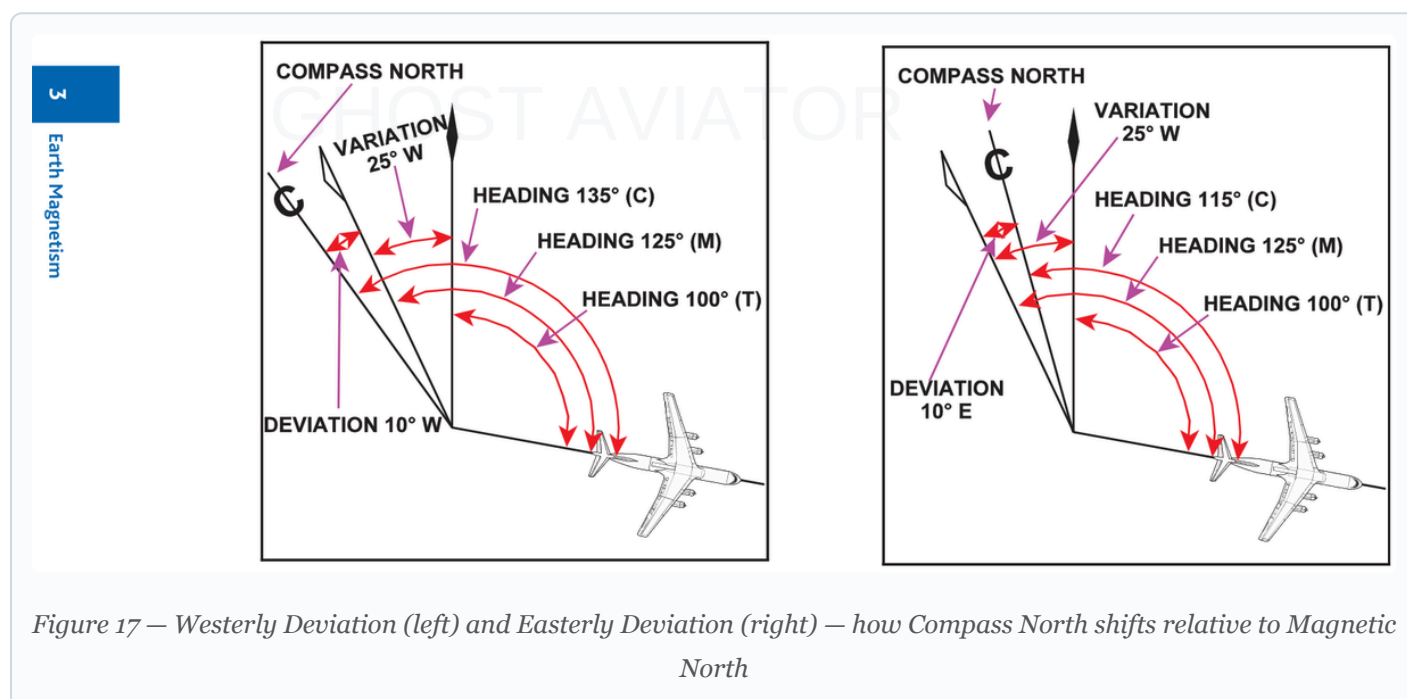
VARIATION EAST — MAGNETIC LEAST (Magnetic heading < True heading)

DEVIATION WEST — COMPASS BEST (Compass heading > Magnetic heading)

DEVIATION EAST — COMPASS LEAST (Compass heading < Magnetic heading)

Worked Examples — Variation

Heading True	Variation	Heading Magnetic	Rule
105°(T)	17°W	122°(M)	West → M best (add)
105°(T)	17°E	088°(M)	East → M least (subtract)



Heading True	Variation	Heading Magnetic	Deviation	Heading Compass
100°	25°W	125°	10°W	135°

Figure 3.18

Heading True	Variation	Heading Magnetic	Deviation	Heading Compass
100°	25°W	125°	10°E	115°

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Figure 18 — Deviation application tables — Heading Magnetic, Deviation, Heading Compass for Westerly and Easterly cases

Worked Examples — Deviation

Heading Magnetic	Deviation	Heading Compass	Rule
125°(M)	10°W	135°(C)	West → C best (add)
125°(M)	10°E	115°(C)	East → C least (subtract)

Full T → M → C Example

°True	Variation	°Magnetic	Deviation	°Compass
100°(T)	25°W	125°(M)	10°W	135°(C)
100°(T)	25°W	125°(M)	10°E	115°(C)

± Notation Example

Deviation 3°E = +3. Heading(M) = 263°. Find Heading(C):

"Deviation East → Compass Least" → C = M - 3 = **260°(C)**

Check: C + deviation = M → 260 + (+3) = 263 ✓

11. All Definitions

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Term	Definition
Heading	Direction of the fore-and-aft axis of the aircraft. May be measured from True, Magnetic, or Compass North.
Variation	Angle between True North and Magnetic North at a point. East if MN is East of TN; West if MN is West of TN.
Deviation	Angle between Magnetic North and the direction indicated by the compass. East if Compass North is East of MN; West if West.
Isogonal	Pecked line on a chart joining places of equal magnetic variation.
Agonic Line	Isogonal joining places of zero variation .
Angle of Dip	Angle in the vertical plane between the horizontal and the Earth's total magnetic force at a point.
Isoclinal	Line on a chart joining places of equal magnetic dip.
Aclinic Line	Isoclinal joining places of zero dip (the magnetic equator).

Note on Isoclinals / Aclinic Lines

Isoclinals and Aclinic Lines do **NOT** appear on standard navigation charts. They appear only in specialist geomagnetic publications.

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Quick Revision — Chapter 3

- Three North datums: **True, Magnetic, Compass**
- Variation = True North to Magnetic North; Deviation = Magnetic North to Compass North
- CADIZ: **Var West = Mag Best; Var East = Mag Least; Dev West = Comp Best; Dev East = Comp Least**
- Max variation = **180°** (between True and Magnetic poles)
- Isogonals converge on **all four poles** (True N, True S, Mag N, Mag S)
- Dip = 0° at magnetic equator; Dip = **90°** at magnetic poles
- Compass most effective where **H is maximum** — midway between magnetic poles (magnetic equator)
- $6 \mu\text{T}$ = compass reliability threshold (H too weak below this)
- Variation changes: Secular (long-term), Annual, Diurnal ($0.1^\circ/\text{day}$), Solar (up to 7°), Local anomalies
- Deviation sign: **$+$ = East, $-$ = West**; $C + D = M$ (algebraic)

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Practice Questions & Detailed Answers

14 MCQ + 1 TVMD table question • Full explanations & distractor analysis

Q1. The sensitivity of a direct reading magnetic compass is:

Anchor: [Sec 7](#)

- (a) inversely proportional to the horizontal component of the Earth's magnetic field
- (b) proportional to the horizontal component of the Earth's magnetic field ✓**
- (c) inversely proportional to the vertical component of the Earth's magnetic field
- (d) inversely proportional to the vertical and horizontal components of the Earth's magnetic field

Correct Answer: (b)

The compass needle is driven by the **horizontal component H**. The larger H is, the greater the directive force and the more reliably the needle aligns with Magnetic North. Sensitivity is therefore *proportional* to H — more H means a more sensitive, reliable compass.

Distractor Analysis:

- (a) Inverse of H would mean the compass works better near the poles — the opposite of reality.
- (c/d) Z is the vertical component — it is unhelpful (causes dip errors) but sensitivity is not inversely proportional to it.

Instructor's Note: Source key: b. Verified. No discrepancy.

Q2. What is the definition of magnetic variation?

Anchor: [Sec 2](#)

- (a) The angle between the direction indicated by a compass and Magnetic North
- (b) The angle between True North and Compass North
- (c) The angle between Magnetic North and True North ✓**
- (d) The angle between Magnetic Heading and Magnetic North

Correct Answer: (c)

Variation is defined as the angular difference between True North and Magnetic North at a given point. More precisely, it is measured from True North to Magnetic North and termed East or West accordingly.

Distractor Analysis:

- (a) Describes Deviation, not Variation.
- (b) The angle between TN and Compass North is the combined effect of Variation + Deviation.
- (d) Magnetic Heading relative to Magnetic North would simply be the heading itself — not meaningful.

Instructor's Note: Source key: c. Verified. No discrepancy.

Q3. At the magnetic equator:

Anchor: [Sec 7](#)

- (a) Dip is zero ✓**
- (b) Variation is zero
- (c) Deviation is zero
- (d) The isogonal is an agonic line

Correct Answer: (a)

The **magnetic equator** (Aclinic Line) is defined as the line of **zero dip**. At the magnetic equator, the total field T is horizontal — $Z = 0$ and $H = T$ (maximum). Compass reliability is highest here.

Distractor Analysis:

- (b) Variation is zero only on the Agonic Line, which does not follow the magnetic equator.
- (c) Deviation depends on the aircraft's own magnetic properties — unrelated to magnetic equator.
- (d) The isogonal at the magnetic equator is not an Agonic Line (except where the magnetic equator and Agonic Line happen to intersect).

Instructor's Note: Source key: a. Verified. No discrepancy.

Q4. Which of these is a correct statement about the Earth's magnetic field?

Anchor: [Sec 7](#)

- (a) It acts as though there is a large blue magnetic pole in Northern Canada ✓**
- (b) The angle of dip is the angle between the vertical and the total magnetic force

- (c) It may be temporary, transient, or permanent
- (d) It has no effect on aircraft deviation

Correct Answer: (a)

In conventional magnetic labelling, a **blue pole** is a South-seeking pole (the end a compass South needle would point to). The Earth's geographic north region acts as a *magnetic south pole* — attracting the north-seeking (red) end of a compass needle. So 'blue magnetic pole in Northern Canada' correctly describes the Earth's field configuration near the Magnetic North Pole.

Distractor Analysis:

- (b) Wrong — dip angle is between the *horizontal* and the total force T , not the vertical.
- (c) Describes aircraft deviation categories, not the Earth's field.
- (d) Wrong — the Earth's field induces magnetism in the aircraft, directly causing deviation.

Instructor's Note: Source key: a. Verified. No discrepancy.

Q5. Where is a compass most effective?

Anchor: [Sec 8](#)

- (a) About midway between the Earth's magnetic poles ✓**
- (b) In the region of the magnetic South Pole
- (c) In the region of the magnetic North Pole
- (d) On the geographic equator

Correct Answer: (a)

The compass is most effective where **H (horizontal component) is greatest**. H is maximum at the magnetic equator, which lies approximately midway between the North and South Magnetic Poles. There $H \approx T$ and $Z \approx 0$.

Distractor Analysis:

- (b/c) At either magnetic pole, $\text{dip} = 90^\circ$, $H \approx 0$ — compass is *least* effective.
- (d) Geographic equator $\neq$ magnetic equator. The geographic equator passes through regions of varying dip.

Instructor's Note: Source key: a. Verified. No discrepancy.

Q6. The value of variation:

Anchor: [Sec 3](#)

- (a) is zero at the magnetic equator
- (b) has a maximum value of 180° ✓**
- (c) has a maximum value of 45°E or 45°W
- (d) cannot exceed 90°

Correct Answer: (b)

The maximum possible variation is **180°** . This occurs at points between the True and Magnetic Poles where TN and MN point in exactly opposite directions. The Agonic Line (zero variation) is unrelated to the magnetic equator.

Distractor Analysis:

- (a) Zero variation occurs on the Agonic Line — not on the magnetic equator.
- (c/d) Both wrong — variation can theoretically reach 180° .

Instructor's Note: Source key: b. Verified. No discrepancy.

Q7. The agonic line:

Anchor: [Sec 4](#)

- (a) is midway between the magnetic North and South poles
- (b) follows the geographic equator
- (c) is the shorter distance between the respective True and Magnetic North and South poles
- (d) follows separate paths out of the North polar regions, one currently running through Western Europe and the other through the USA ✓**

Correct Answer: (d)

The text describes two Agonic Lines from the North pole region: one running through **Western Europe (Stuttgart, Germany)** and the other through **the USA**. Both pass through the poles. This is due to the complex, non-ideal shape of the Earth's magnetic field ('bent bar magnet' analogy).

Distractor Analysis:

- (a) Midway between the magnetic poles would be the magnetic equator — the Aclinic Line, not the Agonic

Line.

(b) The geographic equator has nothing to do with zero variation.

(c) The 180° variation line (not the Agonic Line = 0°) runs between True and Magnetic poles.

Instructor's Note: Source key: d. Verified. No discrepancy.

Q8. The angle between True North and Magnetic North is known as:

Anchor: [Sec 2](#)

(a) deviation

(b) variation ✓

(c) alignment error

(d) dip

Correct Answer: (b)

Variation is precisely the angle between True North and Magnetic North. Deviation is between Magnetic North and Compass North. Dip is the angle between horizontal and the total magnetic force.

Distractor Analysis:

(a) Deviation = MN to Compass North.

(c) Not a standard term in navigation.

(d) Dip = angle of field from horizontal.

Instructor's Note: Source key: b. Verified. No discrepancy.

Q9. The value of magnetic variation on a chart changes with time. This is due to:

Anchor: [Sec 5](#)

(a) Movement of the magnetic poles, causing an increase

(b) Increase in the magnetic field, causing an increase

(c) Reduction in the magnetic field, causing a decrease

(d) Movement of the magnetic poles, which can cause either an increase or a decrease ✓

Correct Answer: (d)

The secular movement of the Magnetic Poles changes the relative geometry between observer, True Pole, and Magnetic Pole. Depending on the direction of pole movement and the observer's location, variation can either increase or decrease — it is not universally one or the other.

Distractor Analysis:

- (a) Says movement always causes an increase — wrong, it depends on location.
- (b/c) The total field strength is not the mechanism for changing chart variation.

Instructor's Note: Source key: d. Verified. No discrepancy.

Q10. Isogonal lines converge as follows:

Anchor: [Sec 4](#)

- (a) At the North Magnetic Pole
- (b) At the North and South Magnetic and Geographical Poles ✓**
- (c) At the North and South Magnetic Poles
- (d) At the Magnetic equator

Correct Answer: (b)

Isogonals converge at **all four poles** — both True (Geographical) poles AND both Magnetic poles. This is because near any pole, all isogonals must converge as the pole is a singular point for direction. The text states explicitly: 'Isogonals converge on both the True and the Magnetic North and South Poles.'

Distractor Analysis:

- (a) Only the North Magnetic Pole — incomplete.
- (c) Both Magnetic Poles but not the Geographical Poles — incomplete.
- (d) The magnetic equator is where isoclinals converge (zero dip), not isogonals.

Instructor's Note: Source key: b. Verified. No discrepancy.

Q11. What is the maximum possible value of dip angle?

Anchor: [Sec 7](#)

- (a) 66°
- (b) 180°

(c) 90° ✓

(d) 45°

Correct Answer: (c)

Maximum dip = 90° , occurring directly over either Magnetic Pole where $Z = T$ and $H = 0$. The field lines enter the Earth vertically.

Distractor Analysis:

(a) 66° is a typical dip angle at mid-latitude UK — a specific local value, not the maximum.

(b) 180° is the maximum possible variation, not dip.

(d) 45° has no physical significance here.

Instructor's Note: Source key: c. Verified. No discrepancy.

Q12. What is the dip angle at the South Magnetic Pole?

Anchor: [Sec 7](#)

(a) 0°

(b) 90° ✓

(c) 180°

(d) 64°

Correct Answer: (b)

At *either* magnetic pole (North or South), the field lines are vertical — dip = 90° . The horizontal component $H = 0$ at both magnetic poles.

Distractor Analysis:

(a) 0° is the dip at the magnetic equator (Aclinic Line).

(c) 180° is maximum variation, not dip — dip cannot exceed 90° .

(d) Not a recognized standard value.

Instructor's Note: Source key: b. Verified. No discrepancy.

Q13. What is a line of equal magnetic variation?

Anchor: [Sec 4](#)

- (a) An isocline
- (b) An isogonal ✓**
- (c) An isogriv
- (d) An isovar

Correct Answer: (b)

An **isogonal** connects points of equal magnetic variation. An isocline (or isoclinal) connects points of equal dip. An isogriv connects points of equal Grid Variation (used in polar grid navigation). 'Isovar' is not a standard aviation term.

Distractor Analysis:

- (a) Isocline = equal dip, not equal variation.
- (c) Isogriv = equal Grid Variation (polar navigation only).
- (d) Not standard terminology.

Instructor's Note: Source key: b. Verified. No discrepancy.

Q14. If variation is West, then:

Anchor: [Sec 10](#)

- (a) True North is West of Magnetic North
- (b) Compass North is West of Magnetic North
- (c) True North is East of Magnetic North ✓**
- (d) Magnetic North is West of Compass North

Correct Answer: (c)

Variation is defined as East or West according to whether *Magnetic North* lies East or West of True North. If Variation is West, Magnetic North is West of True North — therefore **True North is East of Magnetic North**.

Memory check: 'Variation West, Magnetic Best' — $M > T$ numerically. If MN is West of TN, a pilot facing TN would need to look right (East) to see TN relative to MN. So TN is East of MN. ✓

Distractor Analysis:

- (a) True North West of Magnetic North would mean Easterly variation.
- (b) Compass North relative to Magnetic North is Deviation, not Variation.
- (d) Magnetic North West of Compass North is Easterly Deviation.

Instructor's Note: Source key: c. Verified. No discrepancy.

Q15. Fill in the blank spaces in the TVMD table below. Part A uses East/West notation; Part B uses $\pm$ notation (+ = East, - = West).

Anchor: [§10 – CADIZ Rules](#)

Part A — East/West notation:

°True	Variation	°Magnetic	Deviation	°Compass
260	—	291	3E	—
—	10W	—	1E	070
—	7W	001	2E	—
003	17W	—	0	—
306	10E	—	1W	—
036	—	031	2W	—
030	5E	025	2E	023
359	3W	—	2E	—
—	23E	219	2W	221
312	10W	322	3E	319
002	3W	005	1W	006

Part B — $\pm$ notation (+ = East, - = West):

°True	Variation	°Magnetic	Deviation	°Compass
260	—	291	-3	—
—	5E	—	+1	070
—	3W	001	+2	—
022	10W	—	—	035

Part A — Complete Table

°True	Variation	°Magnetic	Deviation	°Compass
260	31W	291	3E	288
061	10W	071	1E	070
354	7W	001	2E	359
003	17W	020	0	020
306	10E	296	1W	297
036	5E	031	2W	033
030	5E	025	2E	023
359	3W	002	2E	000
242	23E	219	2W	221
312	10W	322	3E	319
002	3W	005	1W	006

Part B — Complete Table

°True	Variation	°Magnetic	Deviation	°Compass
260	31W	291	-3	294
076	5E	071	+1	070
358	3W	001	+2	359
022	10W	032	3W	035

Key method (CADIZ): $M = C + D$ (algebraic: +E, -W) | $T = M + V_E$ or $T = M - V_W$

Part A notable rows:

Row 1: $V = M - T = 291 - 260 = 31^\circ\text{W}$. $C = M - D_E = 291 - 3 = 288$.

Row 3: $T = M - V_W = 001 - 7 = -6 = 354^\circ$. $C = 001 - 2 = 359^\circ$.

Row 8: $M = T + V_W = 359 + 3 = 362 = 002^\circ$. $C = 002 - 2 = 000^\circ$.

Row 9: $T = M + V_E = 219 + 23 = 242^\circ$.

Part B notable rows:

Row 1: -3 means 3°W deviation $\rightarrow$ 'Dev West, Comp Best' $\rightarrow C = M + 3 = 291 + 3 = 294^\circ$.

Row 3: +2 means 2°E deviation $\rightarrow$ 'Dev East, Comp Least' $\rightarrow C = M - 2 = 001 - 2 = 359^\circ$.

Row 4: $D = C - M = 035 - 032 = 3\text{W}$ (deviation West).

Instructor's Note: All answers verified against source key. No discrepancies. Green cells = answers; white cells = values given in the question.

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Master Reference Tables — Chapter 3

Key Values

Parameter	Value	Section
Maximum variation	180° (between True & Magnetic poles)	§3
Maximum dip angle	90° (at either Magnetic Pole)	§7
Dip at a mid-latitude UK location	~66°	§7
Residual dip after pendulous suspension	~2°	§7
Compass reliability threshold (H)	6 μT	§8
Diurnal variation change	up to ~0.1°/day	§5
Magnetic storm variation change	up to 7°	§5
Sunspot cycle	11 years	§5
North Magnetic Pole (NERC 2000)	81°N 110°W	§4
South Magnetic Pole (NERC 2000)	63°S 135°E	§4

CADIZ Quick Reference

Rule	Meaning	Formula
Var West, Mag Best	$M > T$ when variation is W	$M = T + V_W$
Var East, Mag Least	$M < T$ when variation is E	$M = T - V_E$
Dev West, Comp Best	$C > M$ when deviation is W	$C = M + D_W$
Dev East, Comp Least	$C < M$ when deviation is E	$C = M - D_E$

Answer Key — Q1–Q14

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans	b	c	a	a	a	b	d	b	d	b	c	b	b	c

No 🚩 flags — all source key answers verified.

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Chapter 3 — Earth Magnetism

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