DOCUMENT

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DOCUMENT TITLE

METEOROLOGY FOR AUSTRALIA

CHAPTER 6 – ATMOSPHERIC DENSITY

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DENSITY

RELATIONSHIP BETWEEN PRESSURE, DENSITY AND TEMPERATURE

a. $P \propto \rho T$

b. $\rho \propto \dfrac{P}{T}$

c. $T \propto \dfrac{P}{\rho}$

Where P is pressure, T is temperature and p is density. So, for example, in (a), if the pressure of the air remains constant but its density reduces, then its temperature must have increased. Or, in (b), if its density remains constant but its pressure reduces, then its temperature must also reduce. Or, in (c), if its temperature remains constant but its pressure increases, then its density must also increase.

DENSITY OF DRY AND MOIST AIR

If it is necessary to calculate values using one of the above formulae, the proportional sign can be replaced by an equality sign provided that a 'gas constant' is introduced into the formula. For example, the gas constant for dry air is

$$\frac{1}{348.4} \quad \text{so:}$$

a) $P = pT \times \dfrac{1}{348.4}$.

b) $p = \dfrac{P \times 348.4}{T}$

where P is in mb
p is in gm/cu metre
T is in degrees Kelvin

c) $T = \dfrac{P \times 348.4}{p}$

If formulae are required for moist air the gas constant is different because molecules of heavier nitrogen and/or oxygen are replaced by lighter water vapour (the atomic weight of N_2 is 14, of O_2 is 16 and H_2O is 10). The formula for density at (b) becomes:

$$p = \frac{348.4\ (P - 3/8\ e)}{T}$$

Where e is the partial pressure of water vapour in mb. **Therefore, moist air is less dense than dry air.**

EQUATIONS CONNECTING PRESSURE, TEMPERATURE AND HEIGHT

a) A rough estimation of the height change, for small pressure changes only, can be made using the formula:

$$\frac{96T \text{ ft/mb}}{P}$$

where T - mean temperature in degrees Kelvin
P - mean pressure in mb

b) A meteorologist uses a more accurate method for calculating the height difference, or thickness, between two pressure levels:

$$H_2 - H_1 = 221.1 \times T \times (\log P_1 - \log P_2)$$

Where $H_2 - H_1$ is the height difference in feet, P_1 is the lower pressure level, P_2 is the upper pressure level (both in mb), and T is the mean temperature in degrees Kelvin between the two pressure levels.

There are a number of 'standard' pressure levels, corresponding to flight levels, which meteorologists use to provide upper wind information. The most important are:

Pressure (hPa)	Height
1013.2	sea level
850	5,000
750	10,000
500	18,500
400	23,500
300	30,000
250	34,000
200	38,500
150	45,000

6.a. Pressure against Height. ISA

Altimeters are calibrated to ISA. QNH is calculated by taking the pressure reading at a station and adding the weight of a theoretical column of air below it, using ISA values to define the weight of the column of air.

6.b. QNH and ISA

CALIBRATION OF ALTIMETERS

Altimeters are calibrated using the thickness formula to convert pressure differences into height differences. P_1 is the lower datum pressure set on the altimeter subscale (QNE, QFE, 1013.2 etc). P_2 is the static pressure at the aircraft level which affects the altimeter capsule. If the aircraft is flown at a constant altimeter height, it maintains a constant pressure level where the capsule experiences the pressure required to make the altimeter read the desired height. Although it is at a constant pressure level in millibars, it will only rarely be at a constant height above mean sea level. The constant pressure level will vary in height if the mean temperature below the aircraft is varying. Because it is not possible to measure the mean temperature, the altimeter is calibrated using the International Standard Atmosphere and this exact atmosphere rarely, if ever, occurs. **Therefore, when on the ground with QNH set, an altimeter will provide only an approximate height above sea level.** All aircraft altimeters are, however, calibrated in the same way and the same P_1 is set on all subscales. So, provided that any instrument and/or static pressure sensor errors have been allowed for, safe vertical separation between aircraft at different flight levels is practicable.

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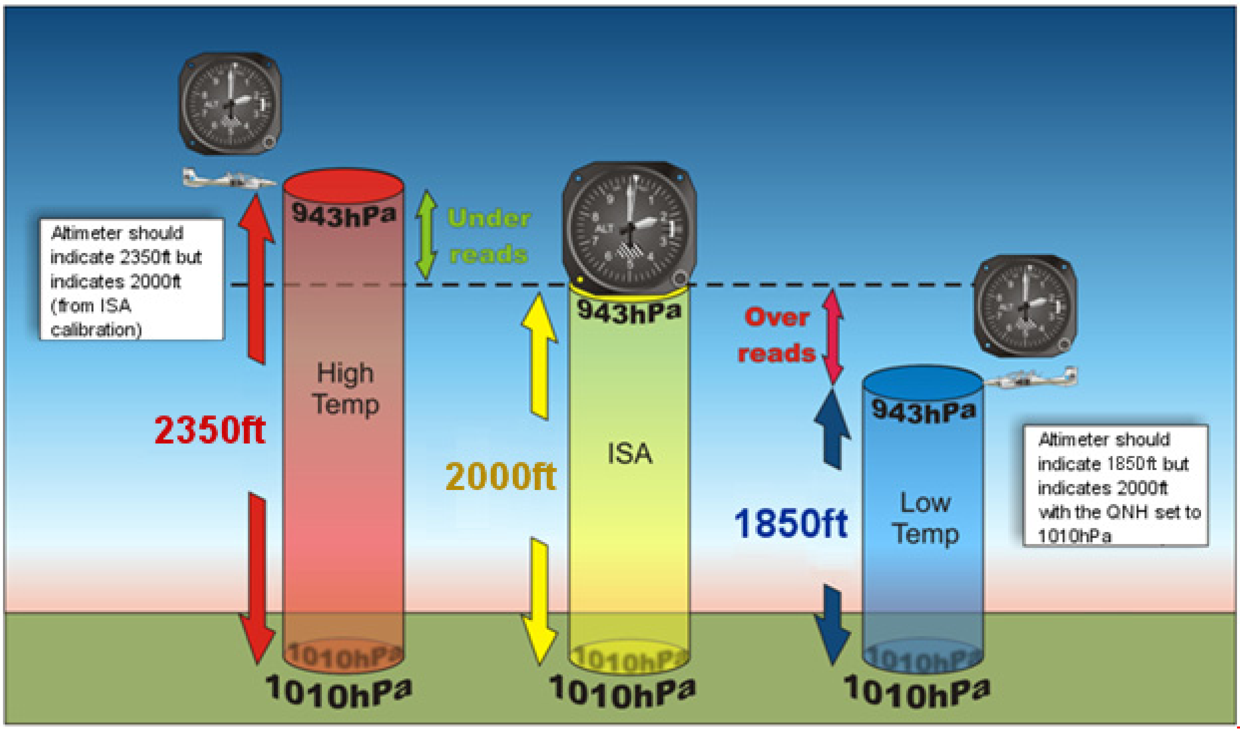
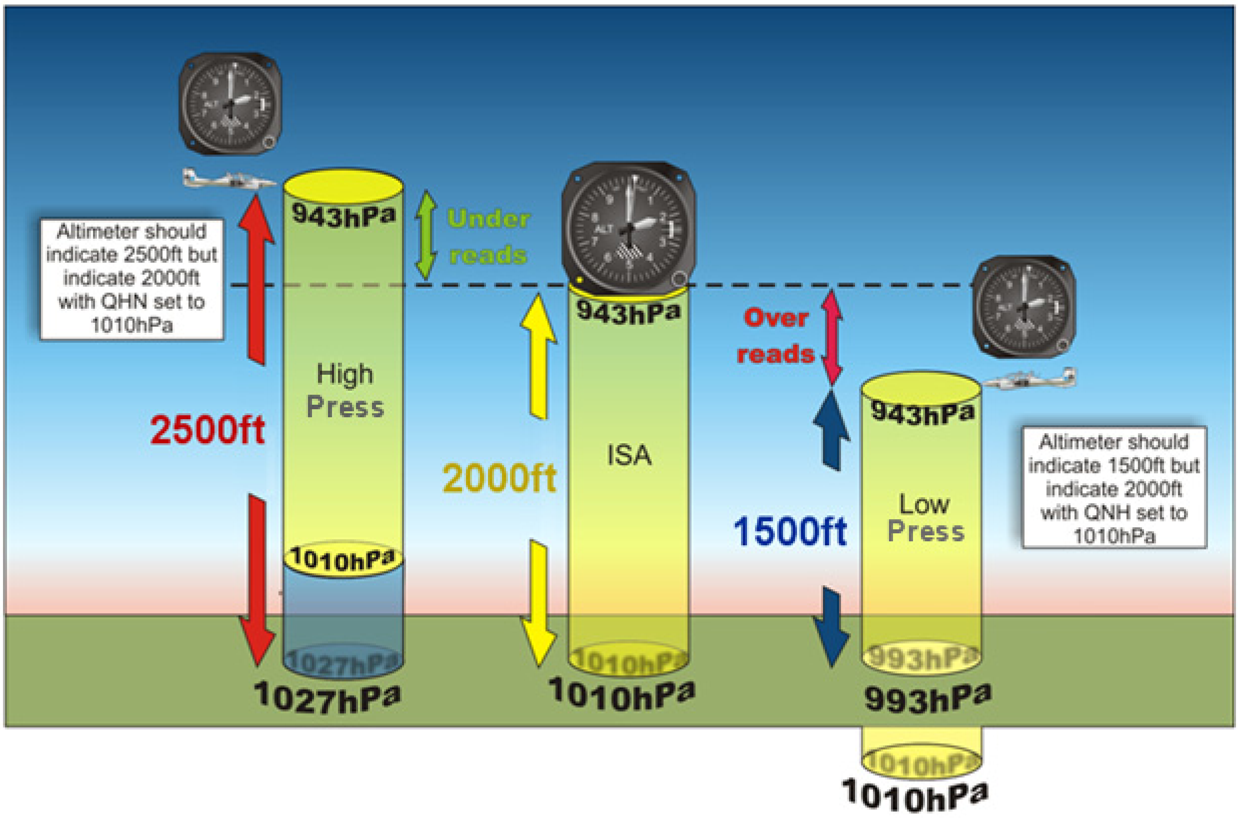
ERRORS



Errors due to temperature differences from ISA



Errors due to pressure differences from QNH

Situation	Result
L.P.	- over reads
Low temperature	- over reads
H.P	- under reads
High temperature	- under reads

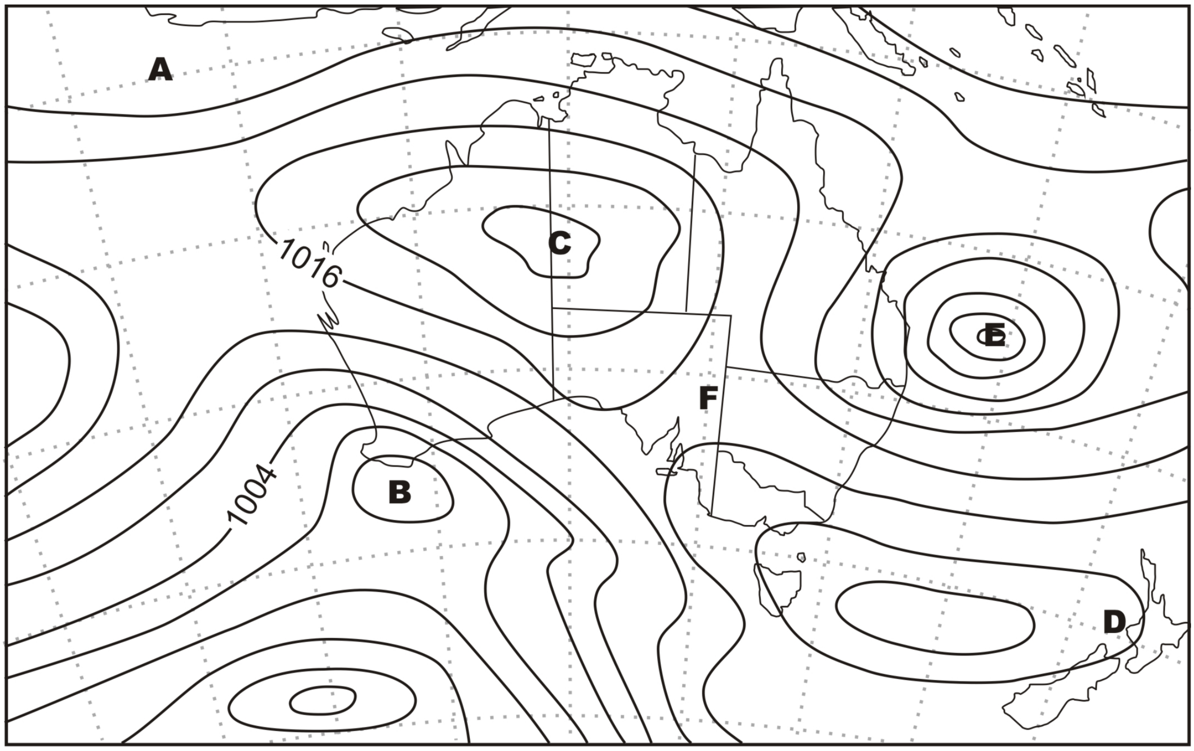
6.c. Errors of Altimetry

"HIGH TO LOW, LOOK OUT BELOW"

SYNOPTIC CHARTS

On the Australian synoptic chart (diagram 6.d)

- i) Label the isobars.
- ii) Indicate the wind direction.
- iii) Name the pressure systems.
- iv) Label all ridges, troughs, cols, secondary low.
- v) Estimate the pressure at A, B, C, D, E and F.



6.d. Australian Synoptic Chart