

## CHAPTER 10 A

### MORE ON METEOROLOGY

#### 1). Atmospheric Pressure

Atmospheric pressure is the pressure with which the atmosphere acts downwards due to its weight.

Pressure decreases with altitude because the column of air is less.

Atmospheric pressure is measured in Millibars (Mb) or Hectare Pascal (Hpa).

The normal atmospheric pressure is about 1013.2 Mb at sea level.

#### 2). The Different layers within the atmosphere. (figure1)

The atmosphere is an envelope of gases surrounding the earth and is split up into different layers (spheres) each of which has its own temperature structure. From the bottom up they are:

##### a). The Troposphere.

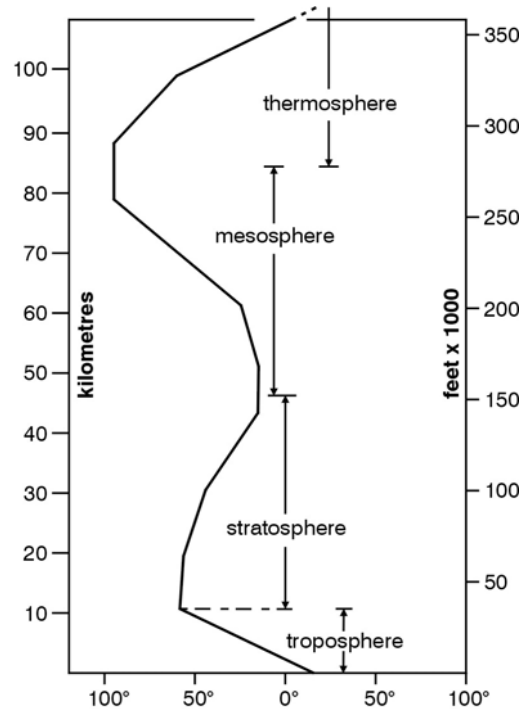
The features that cause our weather occur in this layer of the atmosphere. It is approximately 35 000' thick although it is slightly less at the poles. The average air temperature decreases 2°C per 1000' with increase in height. The upper limit of the Troposphere is known as the Tropopause.

##### b). The Stratosphere

In this layer the air temperature increases slowly with height.

##### c). Mesosphere and Thermosphere: -

Temperature decreases in the Mesosphere and increases in the Thermosphere.



**Fig 1**

#### 3). Some Terms: - (figure 2)

##### a). A 'High'.

Term used for Anticyclones or high-pressure systems. In the Southern Hemisphere the airflow rotates in an anti-clockwise direction. Associated valleys are called ridges.

##### b). A 'Low'.

Term used for depression or low-pressure systems. The airflow rotates in a clockwise direction in the Southern Hemisphere. Associated valleys are Troughs.

##### c). Isobars.

These are lines of equal pressure drawn on a weather map to show different pressure systems.

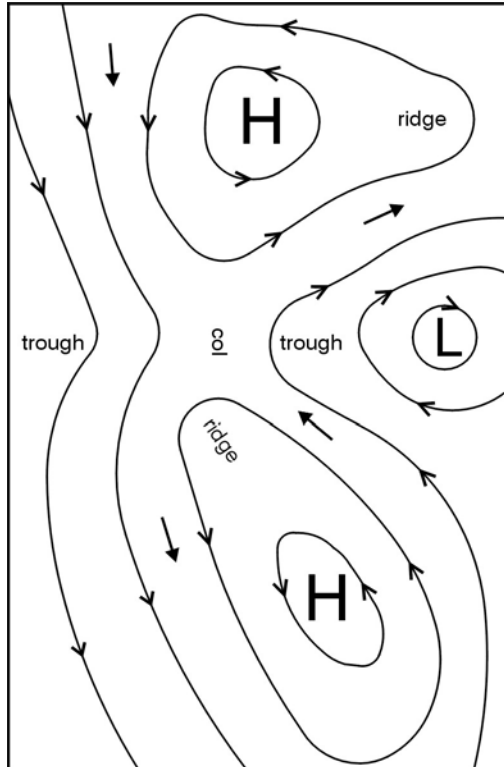


Fig 2

If the earth did not rotate on its axis there would not be any Geostrophic wind.

The air would flow directly to a low-pressure region or flow down any slope.

However the rotation of the earth deflects the moving air. In the Southern Hemisphere it deflects it to the left until the two forces are equal and the air moves directly down the contour lines.

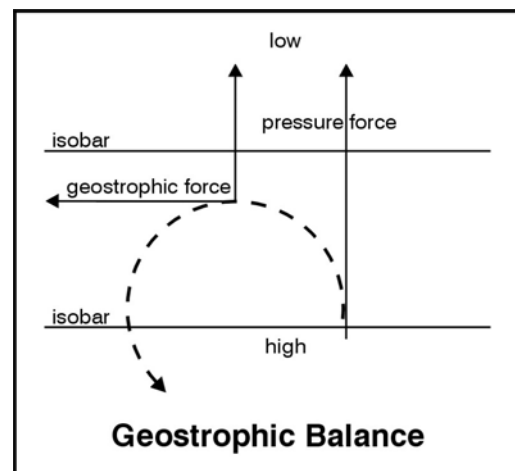


Fig 3

d). Wind (Movement of air).

Pressure Gradients. When the isobars are close together there is a large pressure gradient and the winds will be strong. When the isobars are further apart the wind will be lighter.

#### 4). Buys-Ballot's LAW

If you stand with your back to the wind in the Southern Hemisphere the low pressure is on your right and is opposite in the Northern Hemisphere.

5). Geostrophic Force. (also known as Coriolis Force). (figure 3)

a). The force acts at 90° to direction of movement (Left in S. Hemisphere).

b). It's magnitude proportional to speed of air.

c). The magnitude varies with Latitude, zero at Equator and a maximum at Poles.

6). Lapse Rate.

Lapse Rate defines the way temperature varies with altitude. We can define various types of lapse rates.

a). Environmental Lapse Rate (ELR)

This is the actual variation of temperature with height at a given place. It is measured by sending up a helium filled balloon to which is attached a radiosonde. The radiosonde measures temperature, pressure and humidity and transmits the readings to a ground station.

b). Dry Adiabatic Lapse Rate (DALR)

This is the rate at which the temperature of a dry 'parcel' of air is reduced as it expands in rising through the atmosphere. The given value for this is  $9,8^{\circ}\text{C per Km}$ , or  $3^{\circ}\text{C per 1000 ft}$ .

c). Saturated Adiabatic Lapse Rate (SALR)

The rate at which the temperature of a saturated 'parcel' of air is reduced as it rises is less than the DALR because saturated air, as it cools, gives out water in an invisible form as water-vapour. In the change of state from a gas to liquid, Latent Heat is given off thereby reducing the lapse rate.

The given value varies with temperature  $1.2^{\circ}\text{C per 1000 ft}$ . at  $26^{\circ}\text{C}$

$2.2^{\circ}\text{C per 1000 ft}$ . at  $10^{\circ}\text{C}$

## 7). Stability of the Atmosphere.

Stability depends on how the Environmental Lapse Rate changes with altitude as defined below:

a). Instability.

When the Environmental Lapse Rate is greater than the Dry Adiabatic Lapse Rate we regard the air as being very unstable. ( $\text{ELR} > \text{DALR}$ )

b) Neutral Stability.

When the environmental Lapse Rate is the same as the DALR we regard the air as stable.

c). Inversion.

A temperature inversion occurs when the Environmental Lapse Rate, at some level or levels, is the reverse of the normal (i.e. the temperature increases with altitude instead of decreasing). When the temperature remains constant with height it is called an Isotherm.

During winter a marked haze line can often be seen, which indicates the top of the inversion.

Inversions hamper the development of thermals.

## 8). Development of Thermals.

Thermals develop in the lower layers of the troposphere. Radiation from the sun heats the surface of the earth. Surfaces like hills, ploughed fields, towns etc. are surfaces which will absorb the heat better than their surrounds. The warm ground heats the surrounding air in immediate contact with it by conduction. When air is heated it expands to fill a larger volume thereby becoming less dense

and it will have a tendency to rise This parcel of air will tend to rise until the temperature inside and outside the parcel are equal.

A comparison of the temperature of a rising parcel of air with the environment temperature when cloud forms

Height	Temperatures (Deg C)			
	Environ-ment air	Dry parcel air	Wet parcel air	Excess temp
Surface	25	29	-	+4
1,000 feet	23	26	-	+3
2,000 feet	21	23	-	+2
3,000 feet	19	20	-	+1
3,600 feet	17.8	18.2	18.2	+0.4
	(cloud forms at this level)			
4,000 feet	17	-	17.7	+0.7
5,000 feet	15	-	16.5	+1.5
6,000 feet	13	-	15.3	+2.3
6,500 feet	12	-	14.7	+2.7
	(inversion above this level)			
7,000 feet	13	-	14.1	+1.1
8,000 feet	15	-	12.9	-2.1

Fig 4

**9). Temperature Table.**

Figure 4 above shows an environmental lapse rate of 2° C per 1000ft as compared to the DALR of 3 °C per 1000 ft. The surface air has been heated so that it is 4° C warmer than its environment. As it rises to 1000 ft. the difference is still 3° C, at 2000ft 2° C and 3000ft it is 1° C. When it reaches 4000 ft it is the same temperature as the environment. It may have enough momentum to rise higher to nearly 5000 ft. but it will then sink back to 4000 ft. This is the top of thermal or lift.

**10). Effect of adding moisture.**

In the next example, instead of being completely dry, it has a some moisture in it. (figure 5).

A dew point of 19°C was given a maximum temp of 29°C. The surface dew point meets the dry adiabatic line at this point. The air condenses to form cloud. The point where the two lines meet will be the cloudbase.

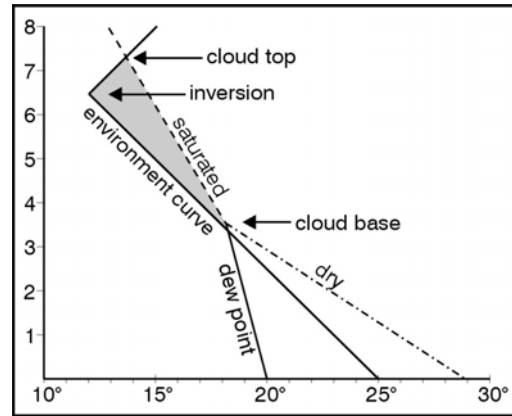


Fig 5

**11). Clouds.**

As air ascends it cools, and if the moisture content is sufficient, condensation will occur to form clouds. The ascent of air may be caused by the following:

Hills: Orographic Clouds (Formed as a cloud on a hill or mountain)

Convection: Thermal (Cumulus Clouds)

Thunderstorms: Cumulonimbus Clouds

Turbulence Clouds: Turbulence related to wind over land from 1000' to 4-5000'

(Stratocumulus/Stratus)

Cloud cover is measured in Octas or Eighths e.g. 4/8, 8/8 (full overcast) etc

**12). Fronts.**

A front is the boundary between two air masses of different density. The frontal surface usually has a slope of about 1:100 with the warmer (less dense) air lying above the colder (more dense) air.

**Cold Front:** Marked on a chart by triangular spikes coloured blue. The warm air is being replaced by cold air.



**Warm Front:** Shown on a weather map with semi-circular blobs on it coloured red. It is cold air being replaced by warm air.



WARM FRONT	COLD FRONT
<p><b><u>Well Ahead</u></b>                      Cirrus increases in amount                      Movement of cirrus may show wind veer with height                      Halo may be visible in cirrostratus                      Pressure begins to fall &amp; wind backs.</p>	<p><b><u>Ahead</u></b>                      Warm Sector cloud, Stratus and Stratocu.                      Possible drizzle.                      Precipitation close to front                      Pressure falls</p>
<p><b><u>Closer to front</u></b>                      Medium cloud thickens &amp; lowers                      Rain belt arrives.                      Patches of ragged low cloud form                      Wind speed increases.                      Dew point rises in the rain.                      Appreciable pressure drop.</p>	<p><b><u>At Passage</u></b>                      Surface wind veers.                      Temp &amp; dew points fall                      Cloud cover breaks up.                      Pressure rises after falling                      Precipitation occurs.</p>
<p><b><u>At Passage</u></b>                      Surface wind veers.                      Pressure ceases to fall &amp; is steady.                      Temp &amp; dew points increase.                      Rain ceases or is replaced by drizzle</p>	<p><b><u>Behind the front.</u></b>                      Pressure rises.                      Visibility improves after precipitation ceases.</p>

**13). Sea breeze Fronts.** (Figure 6)

Sea breezes develop on fairly calm days when sunshine makes the air much warmer inland than out over the sea (the landmass conducts the radiated heat more readily than the water mass).

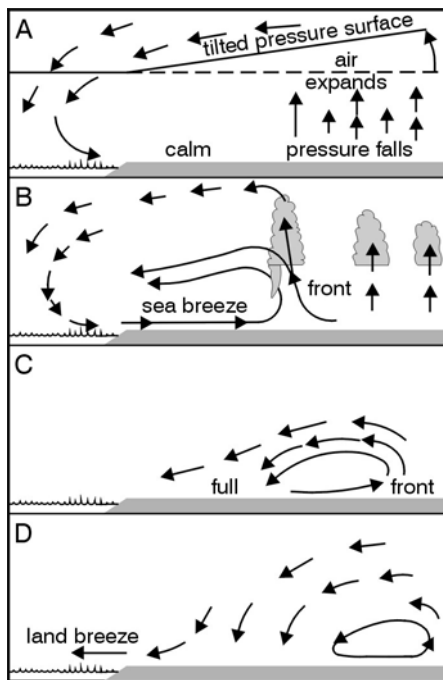
The process is as follows:

- a) Sunshine raises the temperature overland and thermals carry the heat upwards. Heating makes the air expand and tilts the isobaric surface so that it tilts downwards towards the cooler regions over the sea. The air aloft flows down-slope, and this process reduces the total amount of

air overland and thus reduces the pressure. (fig.6A)

- b) At low levels the cooler air over the sea starts to move inland towards the lower pressure. This is the start of the Sea Breeze. There is a boundary between the cooler air from the sea and the warmer air inland. This boundary is like a shallow cold front. It is called a Sea Breeze Front. As it pushes inland a band of rising air is concentrated along its length. (fig.6B)
- c) The heating, which produces the sea breeze, decreases during the late afternoon and ceases before sunset. However the front continues to

move inland in a much weaker state.



**Fig 6**

**14). Hill or Ridge Lift (Figure 7)**

When wind blows against a ridge or mountain, the air is deflected upwards or around the sides. On the lee-ward side it is forced down again.

Figure 7 (a)

Is a smooth windward slope with no sharp edges. The dotted lines show the area of best lift.

Figure 7 (b)

Is a steeper ridge with a sharp edge at the top, where the flow separates. Separation causes an eddy at the top. The wind direction may change by much as 180° on the top so care must be taken when flying close to the top of ridges.

Figure 7 (c)

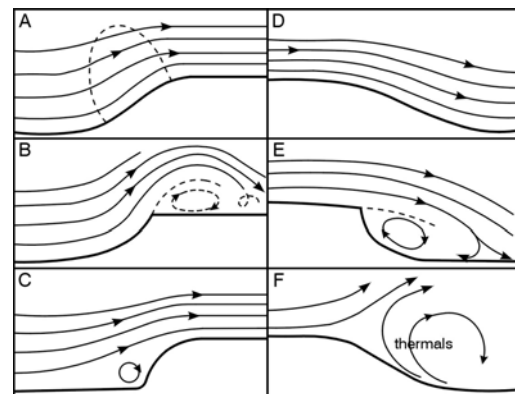
Illustrates a ridge which rises very quickly from the base. This actually traps a local circulation called a Bolster Eddy. Circulation of the air descends to the base of the slope. Gliders approaching low down on a slope expect to get lift but might run into a region of sink and have to make a field landing.

Figure 7 (d)

Is a smooth lee slope down which the air descends without turbulence.

Figure 7 (e)

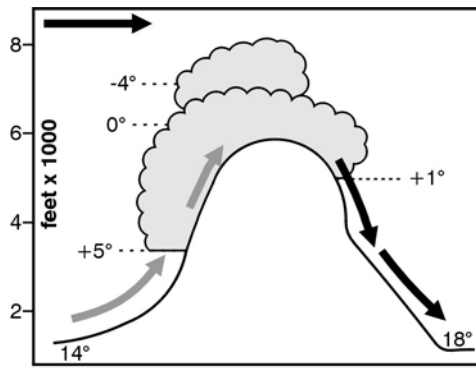
Is a sharp edged slope where the airflow separates at the top leaving an eddy underneath. The airflow will even reverse, creating a small band of lift.



**Fig 7**

**15). Orographic Cloud. (Figure 8)**

This occurs when the condensation level is lower than the top of the mountain. With the wind blowing onto the upwind slope, the air gets deflected upwards and cools adiabatically until it reaches dew point and forms a cloud on the mountain peak. Rain may even occur the lee side of the mountain.

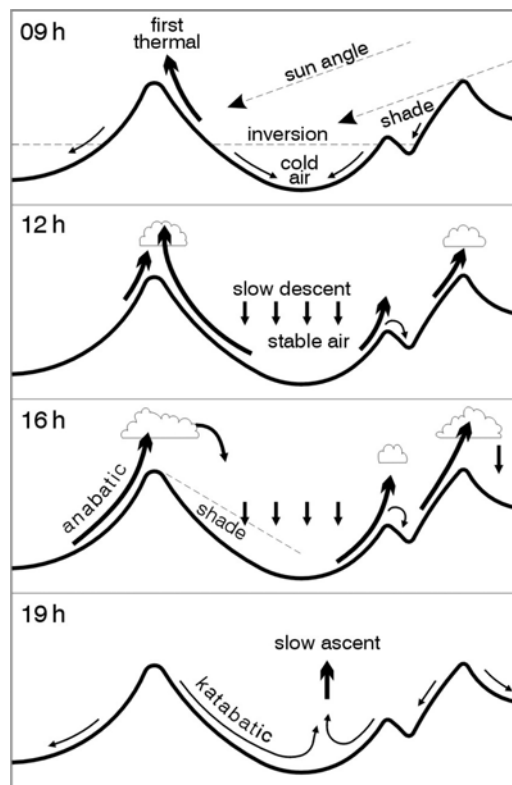


**Fig 8**

**16). Anabatic and Katabatic Winds.**  
(Figure 9)

When long slopes are heated by the sun the air above them is also warmed and winds start to blow uphill, - this is called an Anabatic Wind.

The opposite effect occurs, particularly during the night, when hill slopes lose heat by radiation faster than in the valley. The cooler air descends down the slope to produce a Katabatic Wind in the valley.



**Fig 9**

**17). Wave.** (See figures 1 & 2 in Chapter 18)

Wave occurs when wind flowing over mountains gets pushed down on the lee side and then gets deflected upwards again, bouncing harmoniously, like the ripples seen on the surface of a river flowing over rocks. Unlike water, which is incompressible, air gets compressed and can expand and contract as it bounces down-wind of mountains.

Called Lee Waves, Mountain Waves, Standing Waves.

Basically, when there is wind and an obstruction in its path, there will be wave. It does not necessarily mean very good wave, but under ideal meteorological conditions, waves can be found at great altitudes. A Lockheed U2 found a wave at 60 000 ft, Reflective chaff picked up by radar, detected a wave at 100 000 ft. Theoretically, under ideal conditions, waves will go about 10 times the height of the hill or mountain.

**18). Requirements for good wave.**

- a) The winds at 3000ft should be more than 15 knots and close to right angles to the mountain range.
- b) The wind direction should not alter more than 25° with height.
- c) The wind speed should increase in strength with height.
- d) A temperature inversion, or isotherm, should be at mountain height.

- e) An unstable layer should be present above the inversion.
- f) Another inversion should be present above the unstable layer.

**19). Rotors.**

When waves grow to great amplitudes the streamlines rise and fall at steep angles. There is a region where the air is turning over and over under the crest of the wave. This is called Rotor. The overturning makes the air highly unstable and extremely turbulent. On the ground underneath the rotor the surface wind could be calm and may even be reversed to the normal wind direction.

**20). Lenticular Clouds.**

Above the crest of a rotor, waves are often marked by smooth lens shaped clouds, which form when the airflow flows above the height of the condensation level. These Lenticular clouds mark the shape of the wave. The base of the cloud may be flat or concave. When humidity varies with height, a stack of lenticular clouds may stack up like a pile of plates.

**21). Tephigrams.**

(see also Chapter 10 for actual plots from the Weather Office)

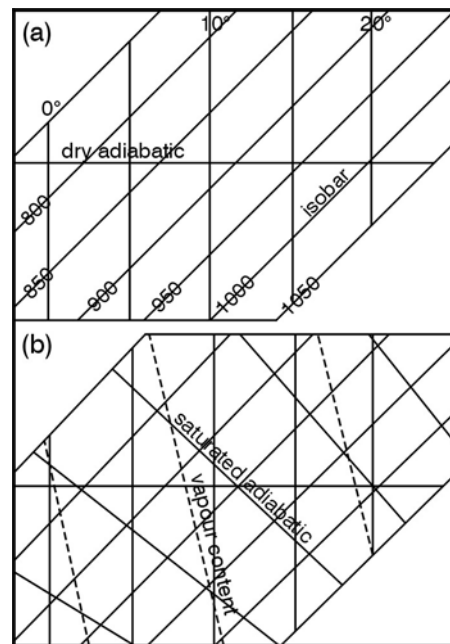
A tephigram is a graph showing temperature, pressure and entropy and is used by meteorologists to predict convective conditions.

The axes of a Tephigram.

Fig.10 (a) The horizontal lines are the **dry adiabats**. The vertical lines  $0^{\circ}$   $10^{\circ}$   $20^{\circ}$  are the isotherms or temperature lines in  $^{\circ}\text{C}$ . The isobars

run diagonally and are labeled in Millibars.

Fig.10 (b) shows two additional sets of lines. The **saturated adiabats** curve upwards from right to left. The pecked lines that run up at a much steeper angle are the **water content lines** and represent water vapor content.



**Fig 10**

*Nicky Oberhofer. (May 2001)  
Graphics by Dave Starke.*