Lecture Number	7	
Lecture Title	WIND – PART 1	
Lecture Items		

Lecture 7 – WIND – PART 1

7.1 ABOUT WIND

- Wind is the motion of the air
- The direction of the wind is given by which direction it is blowing *from*
- For example, a southerly wind means a wind blowing from the South
- Wind speed is measured in *nautical miles per hour (knots)*
- This is close to miles per hour, the conversion being **1** knot = **1.1** miles per hour
- Wind is depicted on weather charts using a shaft to show the direction of the wind, and barbs to show speed
- *A half barb is **5** knots, a full barb is **10** knots, and a filled in triangle barb is **50** knots*

7.2 FORCES AND MOTION

- The velocity of an object is the combination of its speed and the direction in which it is traveling
- Acceleration is defined as the change in velocity. This can be either:
  - A change in speed (either increase or decrease)
  - A change in direction
- If the forces acting on an object are not in balance, then the object will accelerate
- If the forces acting on an object are in balance (or, if there are no forces acting on the object), then the object’s velocity will not change
  - If it were stopped it would stay stopped
  - If it were moving, it would continue to move in the same direction and at the same speed

- An object moving at a uniform speed around a circle is still accelerating, because its velocity is changing (the direction is changing)
- This acceleration is called the centripetal acceleration
- Since it is accelerating, the forces on an object moving in a steady circle are not in balance
- Wind is caused by pressure differences in the atmosphere, which set the air in motion
- There are many forces that act on the air as the below items

7.3 GRADIENT

- The gradient of a scalar is a vector that points in direction of steepest increase of the scalar
- If a contour of the scalar field is plotted (such as isotherms or isobars) the gradient at a given point is a vector that is oriented at 90° to the contours and pointed toward higher values

○ The example below as illustrate in figure (**7.1**) shows the direction of the pressure gradient at several points

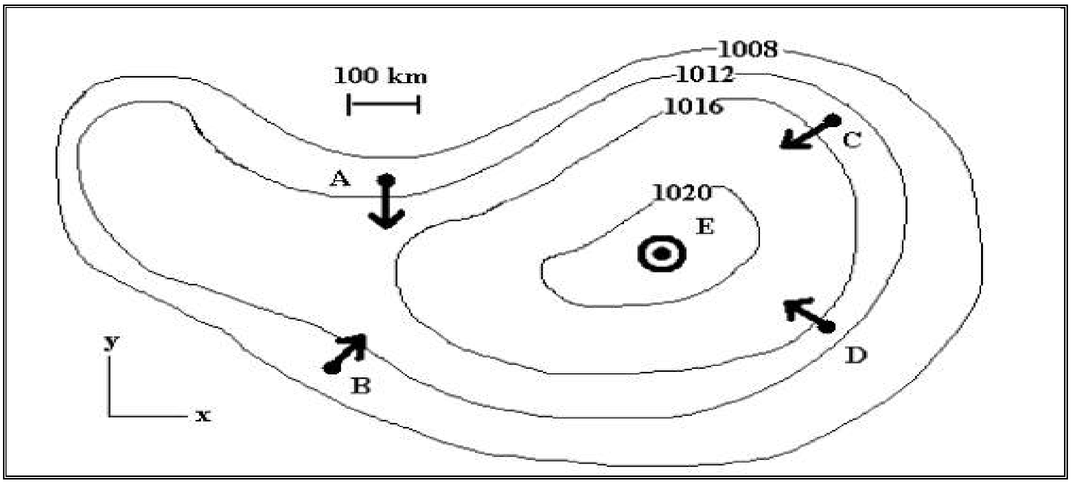


Fig . (7.1) : The direction of the pressure gradient at several points

- The magnitude of the gradient at a point on a contour map can be found by dividing the contour interval by the shortest distance between contours across the point
- In the example below as illustrate in figure (**7.2**) the magnitude and direction of the pressure gradient is shown

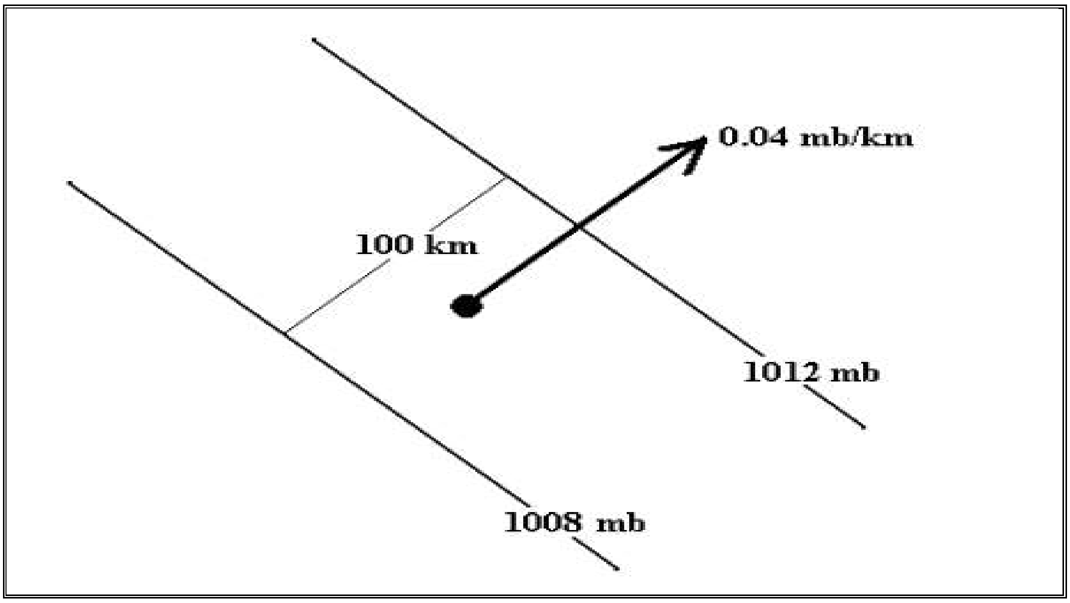


Fig . (7.2) : The magnitude and direction of the pressure gradient

- The magnitude was found by

$$\left|\nabla p\right| \cong \left|\frac{\Delta p}{\Delta n}\right| = \frac{1012mb - 1008mb}{100km} = 0.04mb / km$$

- The magnitude of the gradient increases if the contours become closer together, and decreases as they get farther apart
- When the contours are packed closely together it is often referred to as a *tight gradient*
- When the contours are far apart it is often referred to as a *loose gradient*

7.4 PRESSURE GRADIENT FORCE (PGF)

- This is the force caused by the difference in air pressure on opposite sides of the air parcel
- This force tries to push the parcel toward lower pressure
- The acceleration due to the pressure-gradient force is

$$\vec{a}_{PGF} = -\frac{1}{\rho}\nabla p$$

- The subscript just shows that this is the acceleration due to the pressure gradient force, and is not necessarily the total (or net) acceleration
- Notice that the pressure-gradient acceleration is opposite to the pressure gradient itself
- *The pressure-gradient acceleration is always perpendicular to the isobars and pointing toward lower pressure*

- The spacing of the isobars is called the *pressure gradient*
- A closer spacing means a *tighter* or *steeper* gradient
- A greater spacing means a *looser* gradient
- The tighter the pressure gradient, the stronger the pressure gradient force will be as shown in figure (**7.3**)

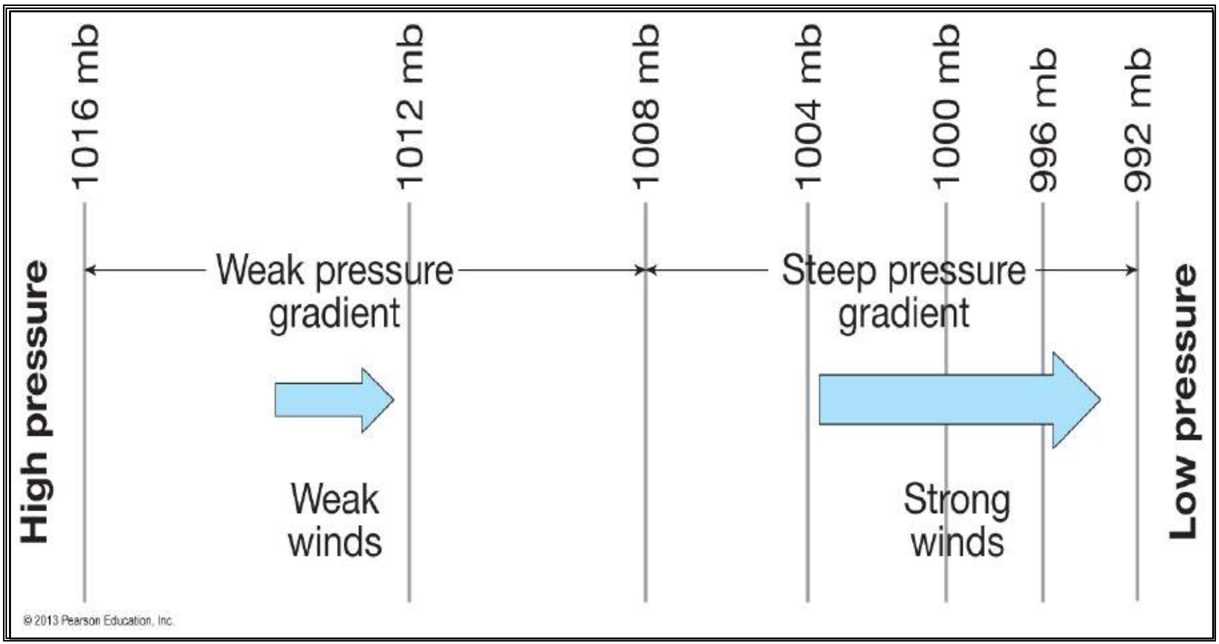


Fig.(7.3) : Pressure Gradient Force (PGF)

7.5 CORIOLIS FORCE (CF) OR (COR)

- This force is a result of the fact that we are on a rotating planet
- It is proportional to speed, and always acts to the right of the motion in the Northern Hemisphere (and to the left of the motion in the Southern Hemisphere) as shown in figure (**7.4**)

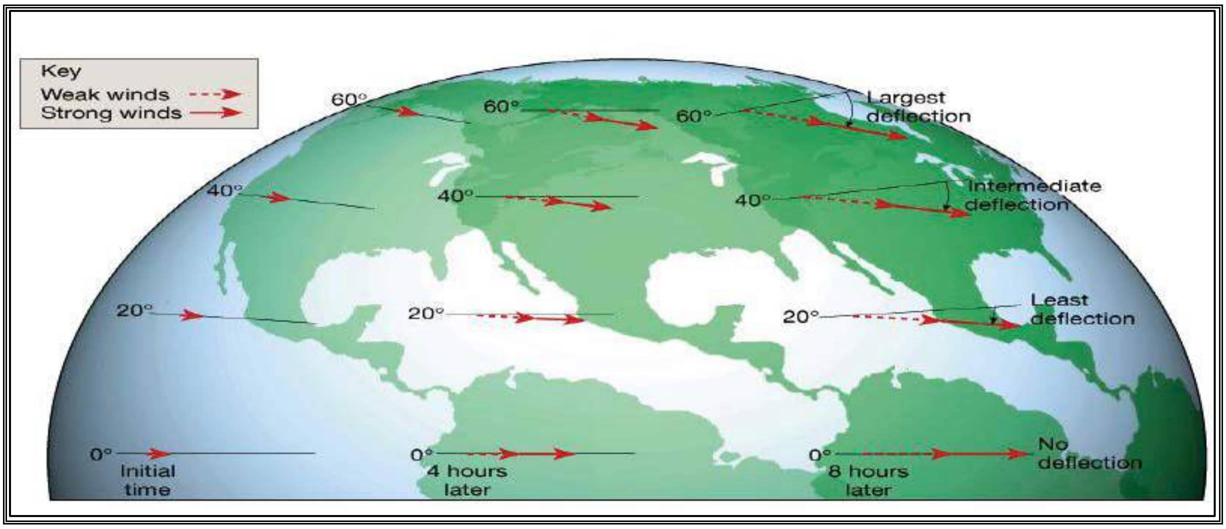


Fig.(7.4) : Coriolis Force (CF)

- The magnitude Coriolis acceleration is linear in speed, and is given as

$$\left|\vec{a}_{COR}\right| = fV$$

Where f is the Coriolis parameter,

$$f = 2\Omega \sin\phi$$

- **Ω** is the angular speed of the Earth, and **Ø** is latitude
- Since the Earth rotates through 2π radians in one Sidereal Day (23.93447 hours), the angular speed of the Earth is

$$\Omega = \frac{2\pi}{23.93447x3600} = 7.292x10^{-5}s^{-1}$$

7.6 FRICTION FORCE (F_r) OR (FR)

- Near the surface of the Earth we have to include the effects of friction
- This adds a third force to the balance of forces
- Friction is only important within a few kilometers of the earth's surface (in what is known as the *planetary boundary layer*)
- Above the planetary boundary layer we can assume that there is no friction
- Friction always acts to slow the air down, so it is always acting opposite to the direction of motion as shown in figure (**7.5**)

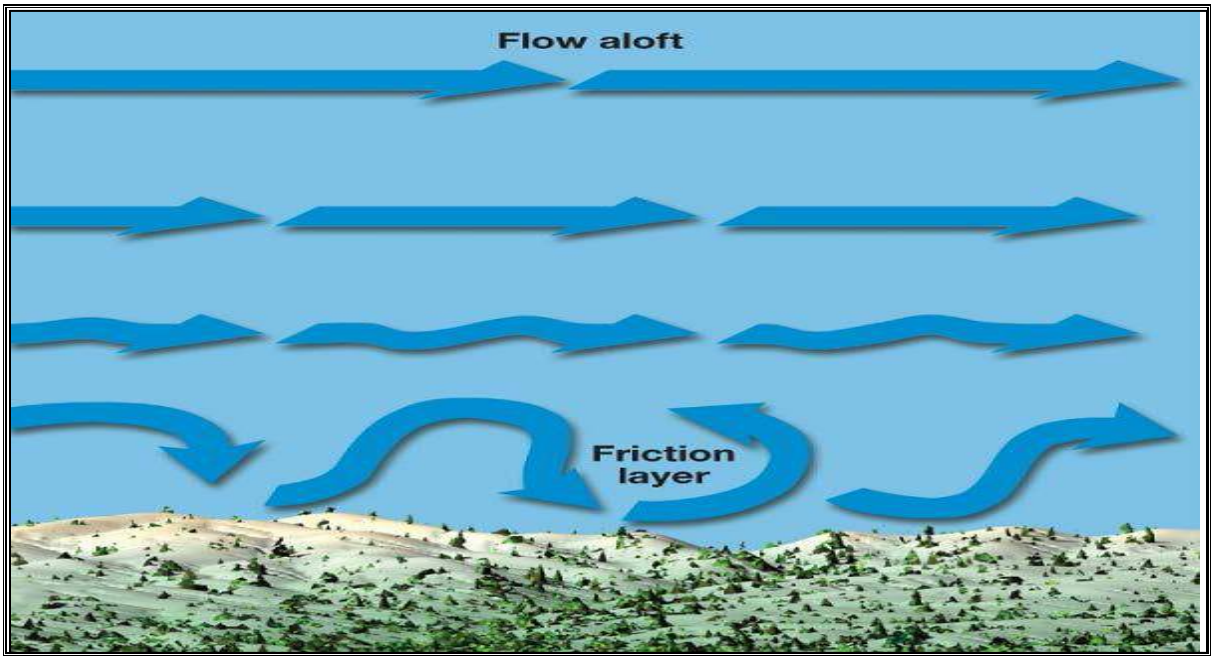


Fig.(7.5) : Friction Force

- This causes the wind to blow slightly across the isobars toward lower pressure
- *In order for the three forces to be in balance the wind must point slightly toward lower pressure and slightly away from higher pressure*
- The force balance for steady flow with friction is shown in the figure (**7.6**)

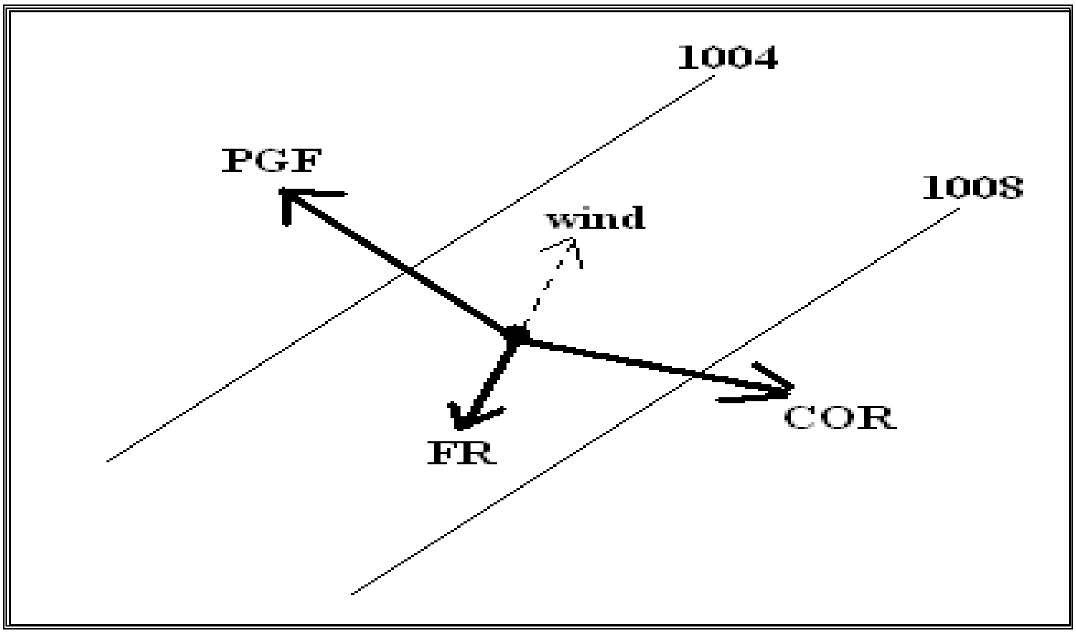


Fig. (7.6) : Force balance in straight flow with friction (FR). In order for the three forces to balance, the wind must blow slightly across the isobars toward low pressure.

- In a low-pressure system near the surface of the Earth, friction will cause the wind to blow toward the center of the low
- This results in convergence within the low, and upward vertical motion
- In a high-pressure system near the surface of the Earth, friction will cause the wind to blow away from the center of the high
- This results in divergence within the high, and downward vertical motion
- This is why lows are associated with upward motion, clouds, and bad weather, while highs are associated with downward motion (*subsidence*), clear skies, and fair weather

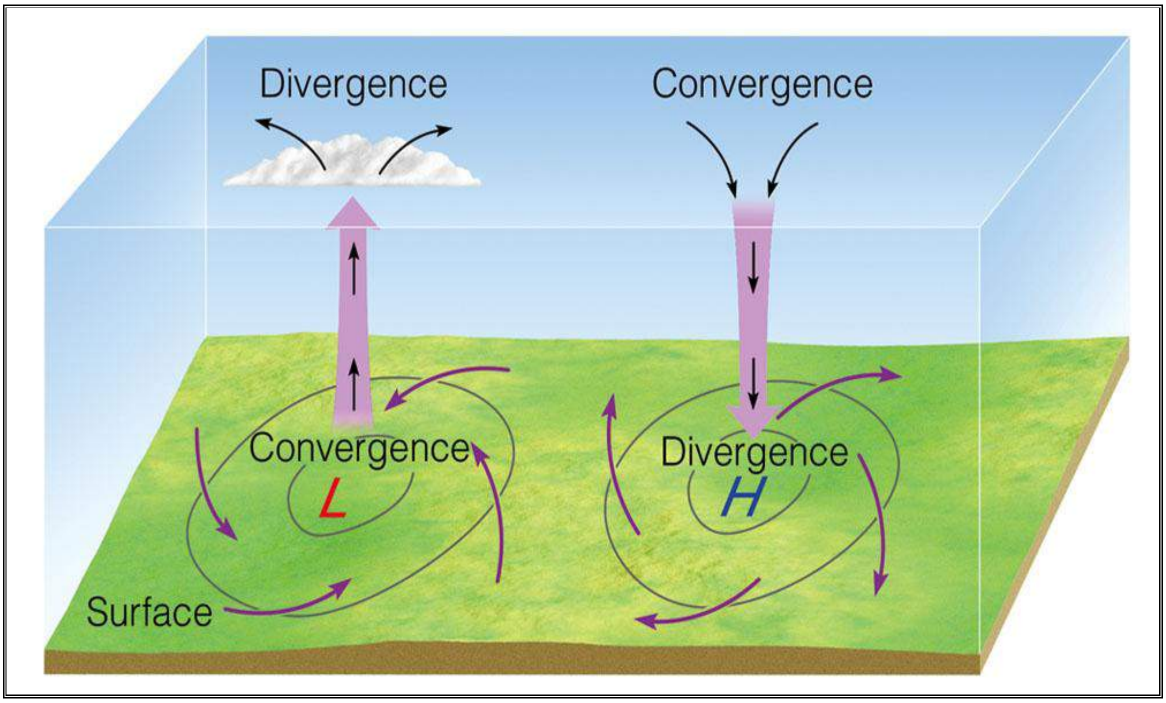
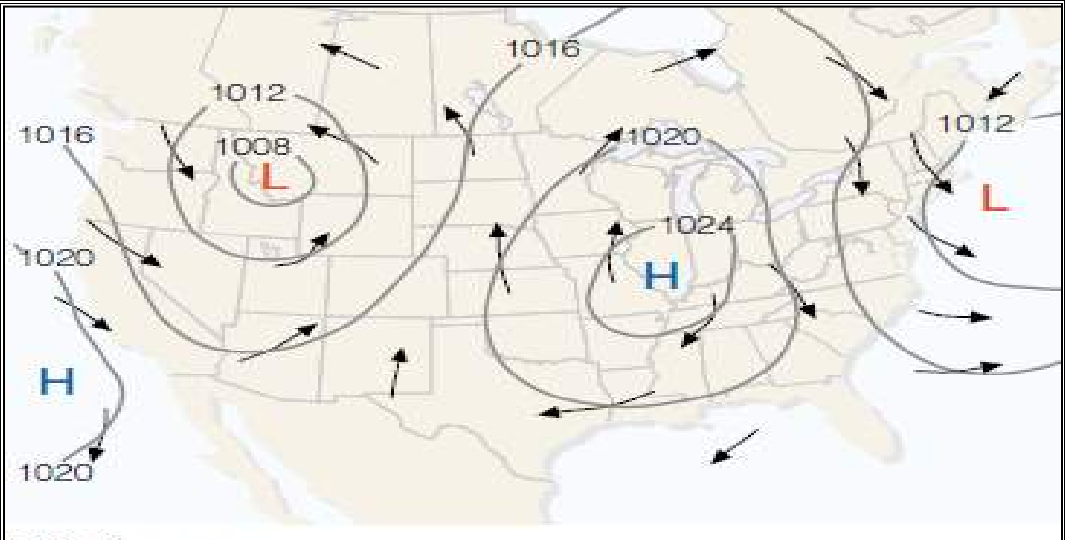


Fig.(7.7) : Winds and air motions associated with surface highs and lows in the Northern Hemisphere.

7.7 Surface and Upper-Air Maps

- Figure (**7.8**) shows a simplified **surface map**, the solid dark lines on the surface map are **isobars lines**—lines that connect points of equal pressure above sea level
- The **surface map** shows areas of high and low pressure and arrows that indicate *wind direction—the direction from which the wind is blowing*
- The large blue ***H***'s on the map indicate the centers of high pressure, which are also called **anticyclones**
- The large red ***L***'s represent centers of low pressure, also known as *depressions*, **mid-latitude cyclones**
- In the Northern Hemisphere the winds blow counterclockwise and inward toward the center of the lows and clockwise and outward from the center of the highs



(a) Surface map

Fig.(7.8) : Surface map

- Figure (**7.9**) shows an **upper-air map**, the solid dark lines on the map upper –air map are **contour lines**—lines that connect points of equal elevation above sea level
- This particular isobaric map shows height variations at a pressure level of **500** mb (which is about **5600** m or **18,000** ft above sea level)
- Hence, this map is called a ***500-millibar map***
- Consequently, *contour lines of low height represent a region of lower pressure, and contour lines of high height represent a region of higher pressure*
- Dashed lines are **isotherms -** lines of equal temperature in °C
- The contour lines are not straight, however, they bend and turn, indicating **ridges** *(elongated highs)* where the air is warmer and indicating depressions, or **troughs** *(elongated lows)* where the air is colder

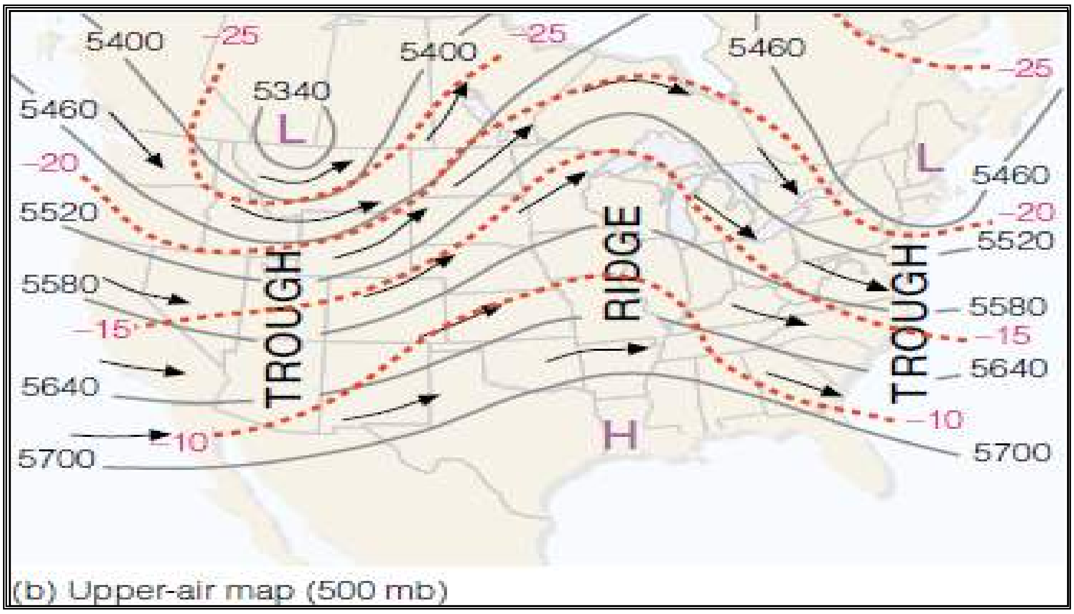


Fig.(7.9) : Upper-air map