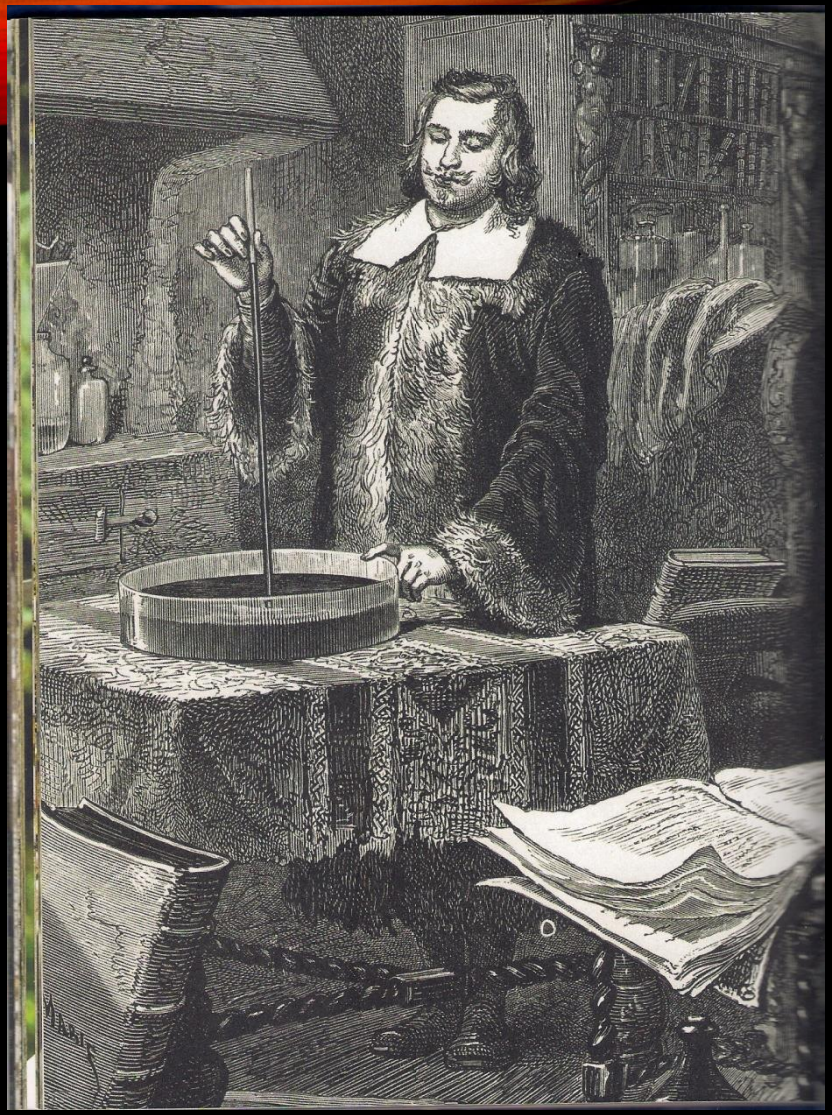
Understanding weather and the weather forecast

Week 4 - How the atmosphere responds when there is a pressure difference

Terry Hart



Torricelli also recognised that for a denser liquid, the column would be shorter. He used mercury and showed that a column of only about 760 mm (30 inches) could be supported.

"We live immersed at the bottom of a sea of elemental air, which by experiment undoubtedly has weight, and so much weight that the densest air in the neighbourhood of the surface of the earth weighs about one four-hundredth part of the weight of water."

Torricelli, 1644

Torricelli observed that the mercury level changed from day to day and he noticed a link between pressure and weather.

“Winds are produced by differences of air temperature , and hence density, between two regions of the earth.”

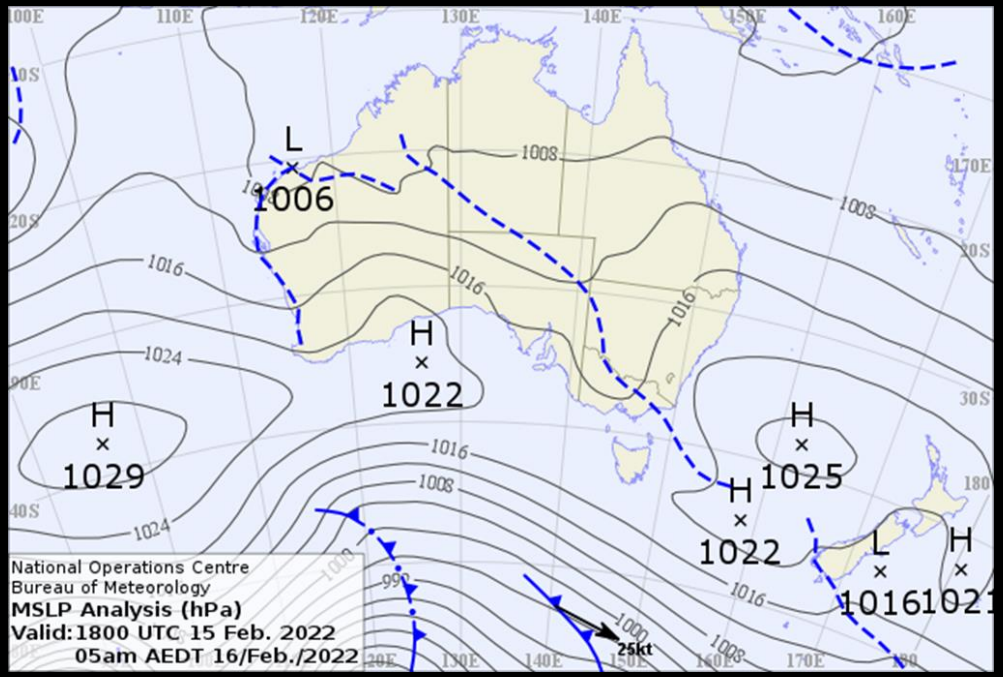
Scientists after him (including Blaise Pascal) used his barometer to show that pressure was lower at higher altitudes. This became the basis for the **altimeter**, used to measure altitude.

Barometers measure the pressure where they are, which is generally at some altitude. This pressure is called the station level pressure

However, to be able to isolate the effect of weather systems the station level pressures need to be adjusted to a standard level

Mean Sea Level (MSL) is the most common standard level and the pressure is called the **Mean Sea Level Pressure** (MSLP)

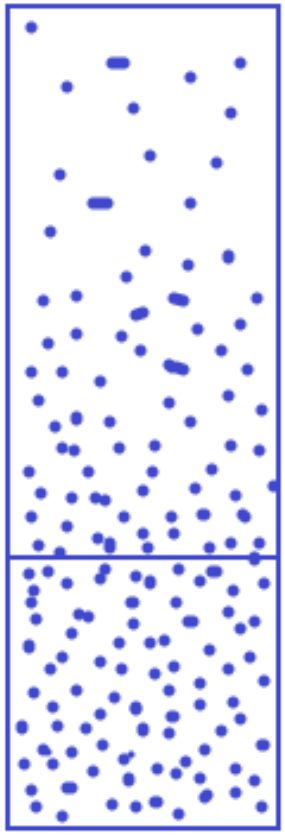
MSLP is a hypothetical value obtained by imagining that the column of air extends down through the land to mean sea level, using a typical temperature profile.



Effect of temperature on pressure.

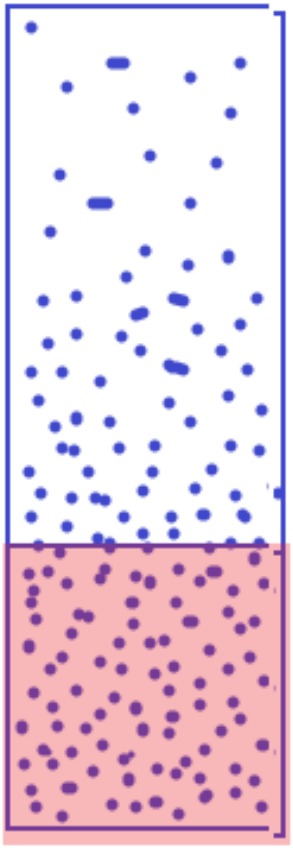
https://youtu.be/_e9L8F2eYXM

What causes the pressure to change?
And how does the atmosphere respond to differences in pressure?

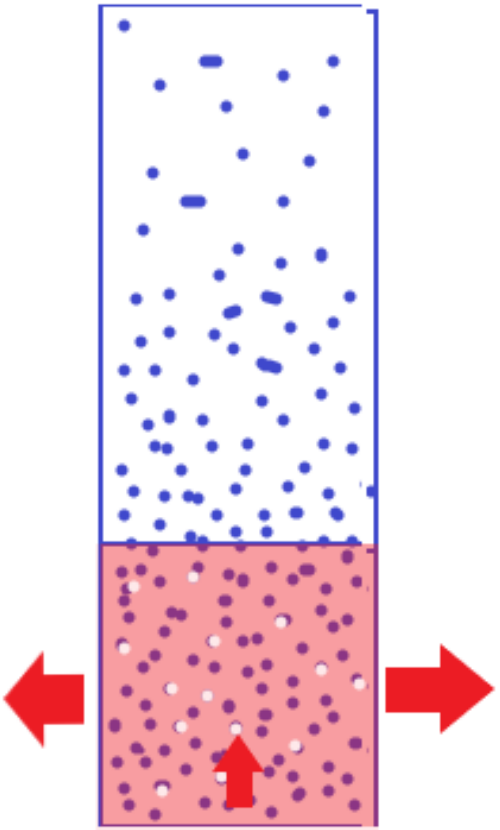


Pressure 1

Add some heat to the bottom layer

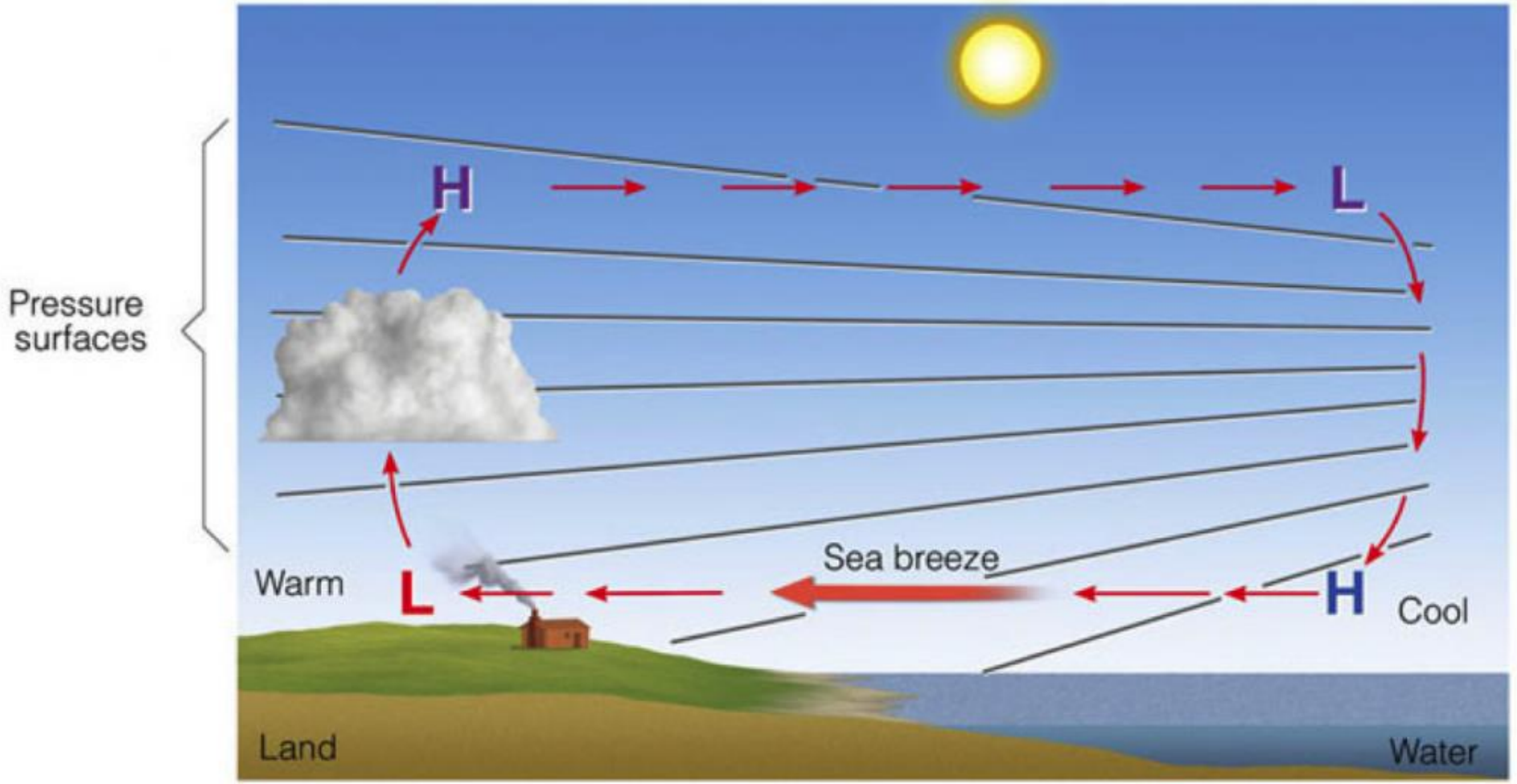


Pressure in the layer increases - and some air moves out

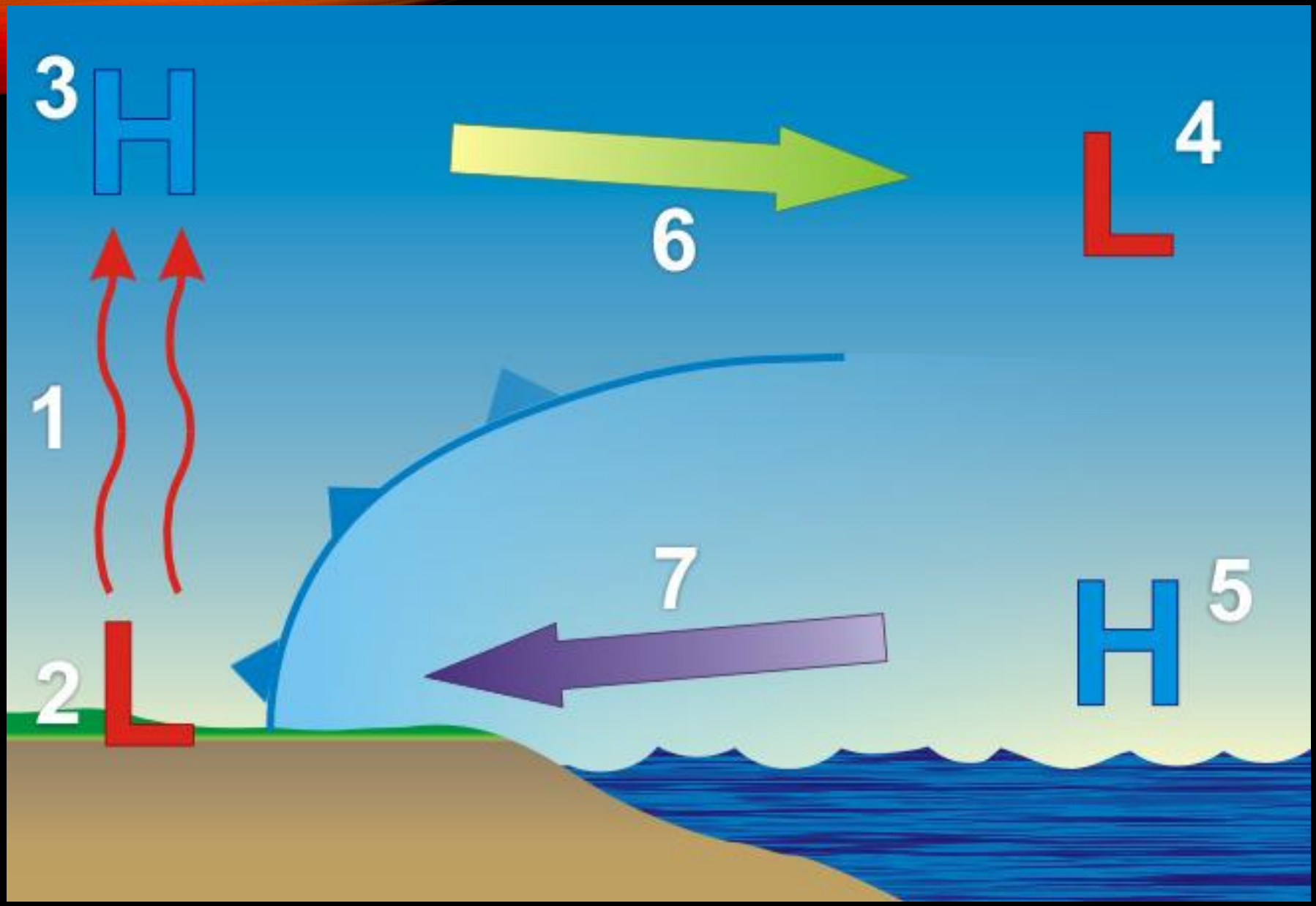


leading to lower pressure

An example is a sea breeze where the land is heated by the sun



(a) Sea breeze


3
H
6
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4
1
7
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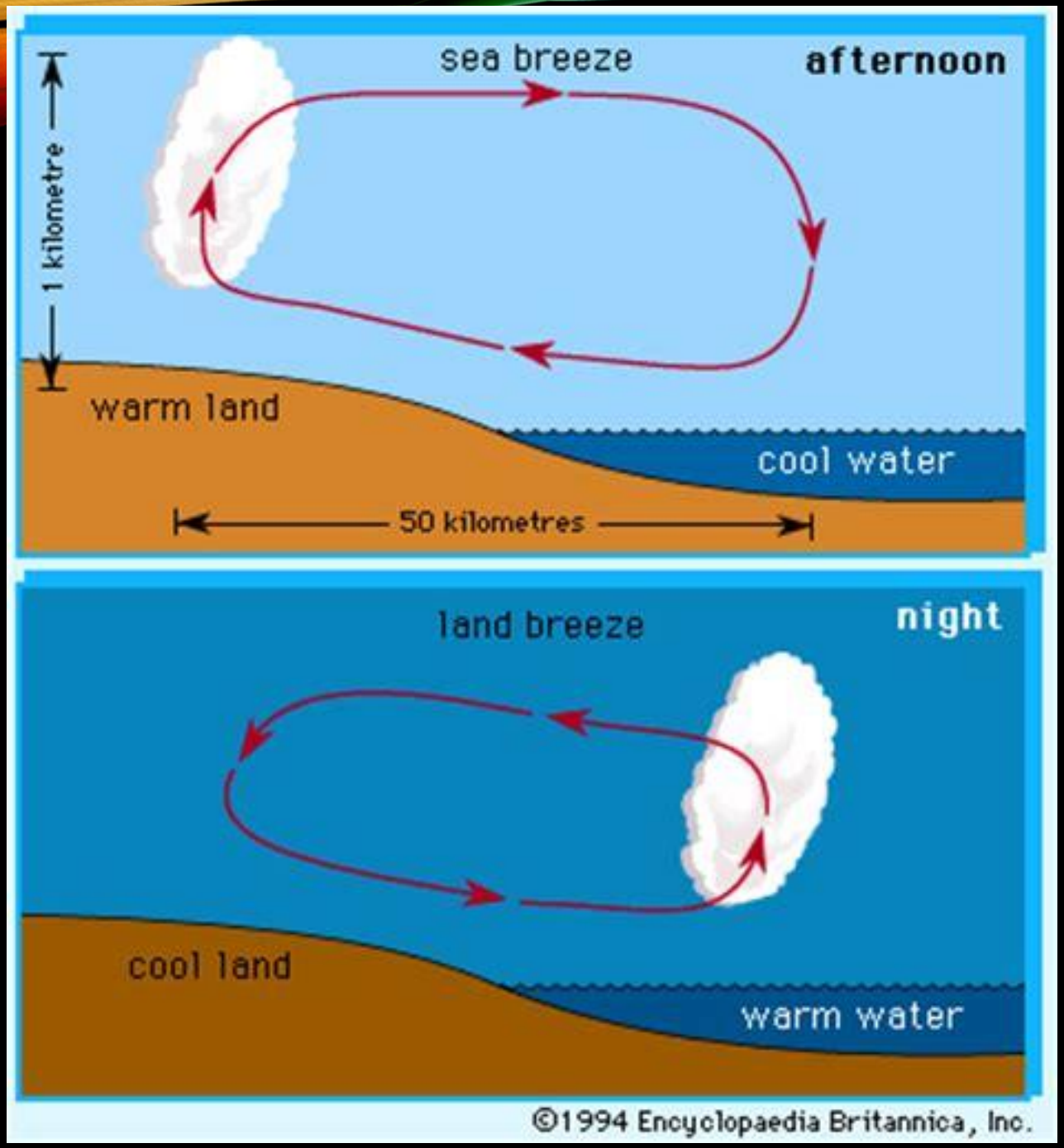

sea breeze
afternoon
1 kilometre
warm land
cool water
50 kilometres
land breeze
night
cool land
warm water
©1994 Encyclopaedia Britannica, Inc.

People using barometers noticed that changes in pressure were related to changes in the weather, and particularly that storms were associated with low pressure.

Before rapid communication:

- not possible to make a map of the weather or to track storms
- there developed tentative ideas that storms moved
- Some maps were made on past storms by collecting and analysing reports.

Turning point - The **telegraph** made mapping the weather in close to real-time possible.

Mid 19th century controversy about the wind flow in storms:

- Did winds circulate around a low?
- Or did winds blow into a low?
- Spiralling winds – both circular and inflow components?.

It seems logical that if there is a pressure difference, air should move from areas of high pressure to areas of low pressure. If not, why not?

Why the three basic rules for reading weather maps in our part of the world?

- The wind blows clockwise around lows, and anticlockwise around highs (in the Southern Hemisphere; the opposite way in the Northern Hemisphere)
- the closer the isobars (lines of equal pressure), the stronger the wind
- rain and thunderstorms tend to occur in the low pressure zone between highs.

The **Monty Python** Galaxy Song in **The Meaning of Life** gives a clue.

The **Monty Python** Galaxy Song **in The Meaning of Life** gives a clue:

Whenever life gets you down, Mrs.Brown
And things seem hard or tough
And people are stupid, obnoxious or daft
And you feel that you've had quite enough

Just remember that you're standing on a planet that's evolving
And revolving at nine hundred miles an hour
That's orbiting at nineteen miles a second, so it's reckoned
A sun that is the source of all our power

The sun and you and me and all the stars that we can see
Are moving at a million miles a day
In an outer spiral arm, at forty thousand miles an hour
Of the galaxy we call the 'milky way'
.....
*(**Eric Idle**, John Du Prez)*

900 miles per hour – tangential speed of rotation?

- Is that correct?
- Is it true everywhere?

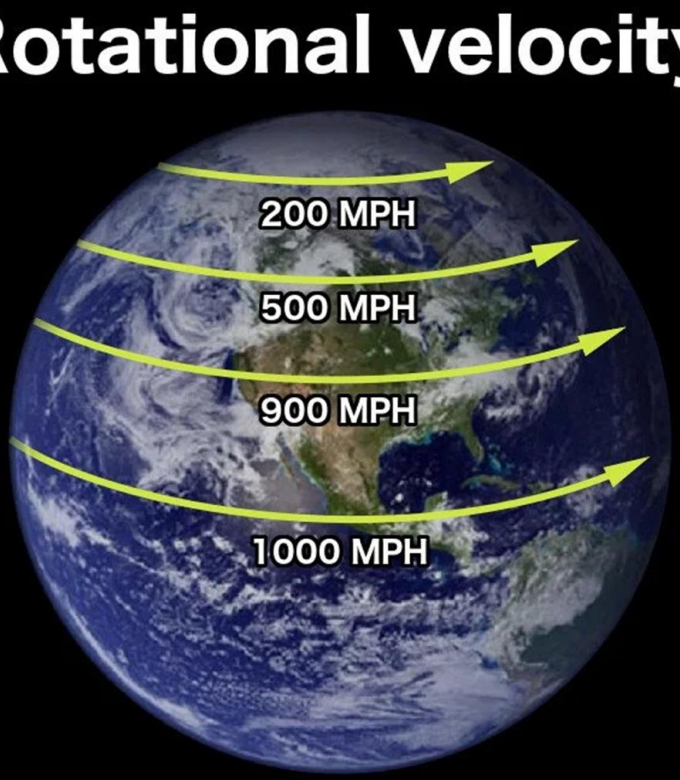
Actually **at the Equator** it is **1040 mph** (1674 km/h or 465 m/s)

To find the speed at other latitudes, multiply by the cosine of the latitude.

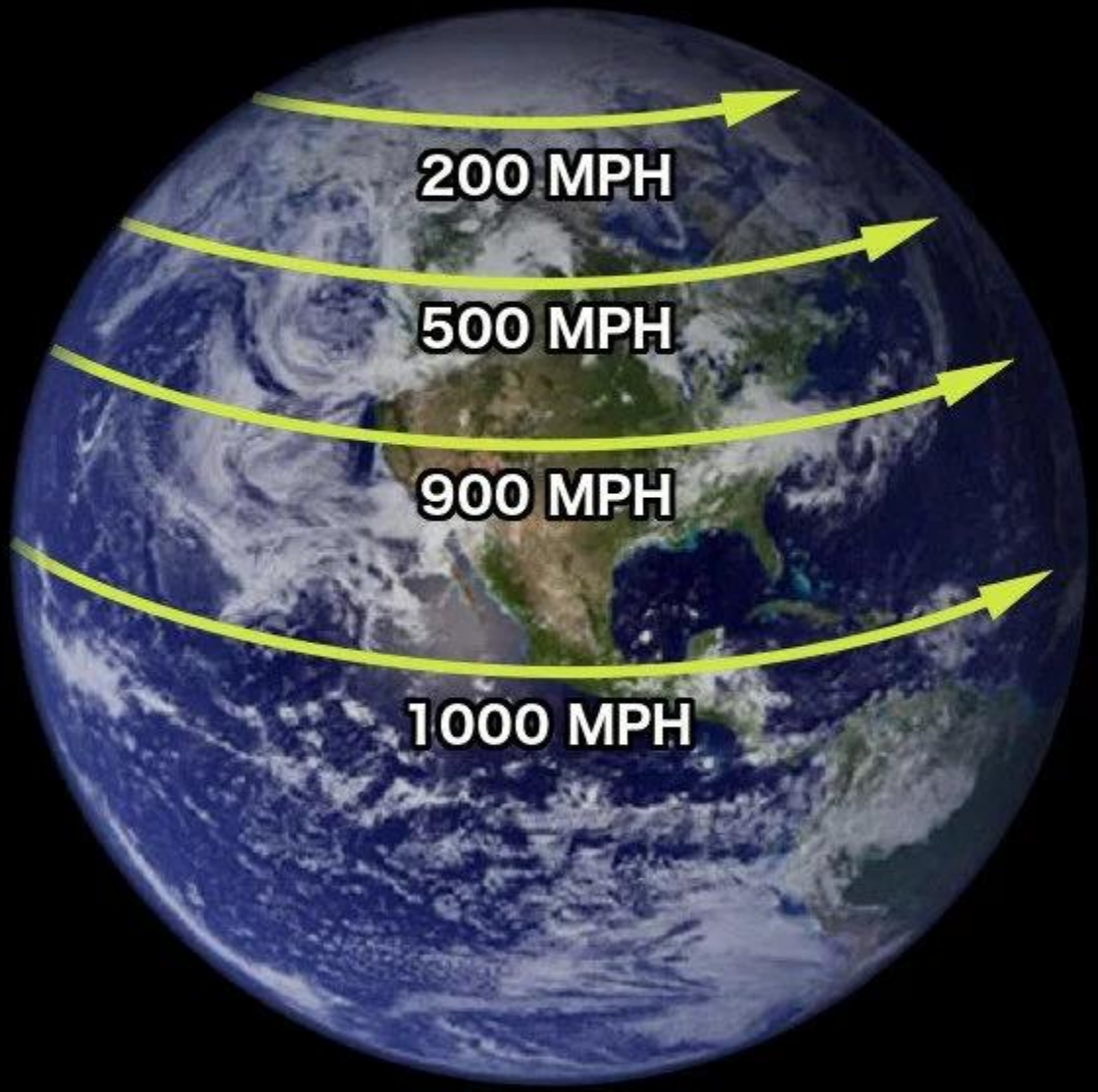
e.g. Melbourne at 38°S:

1674 x 0.788 = 1319 km/h

(819 mph)



Rotational velocity



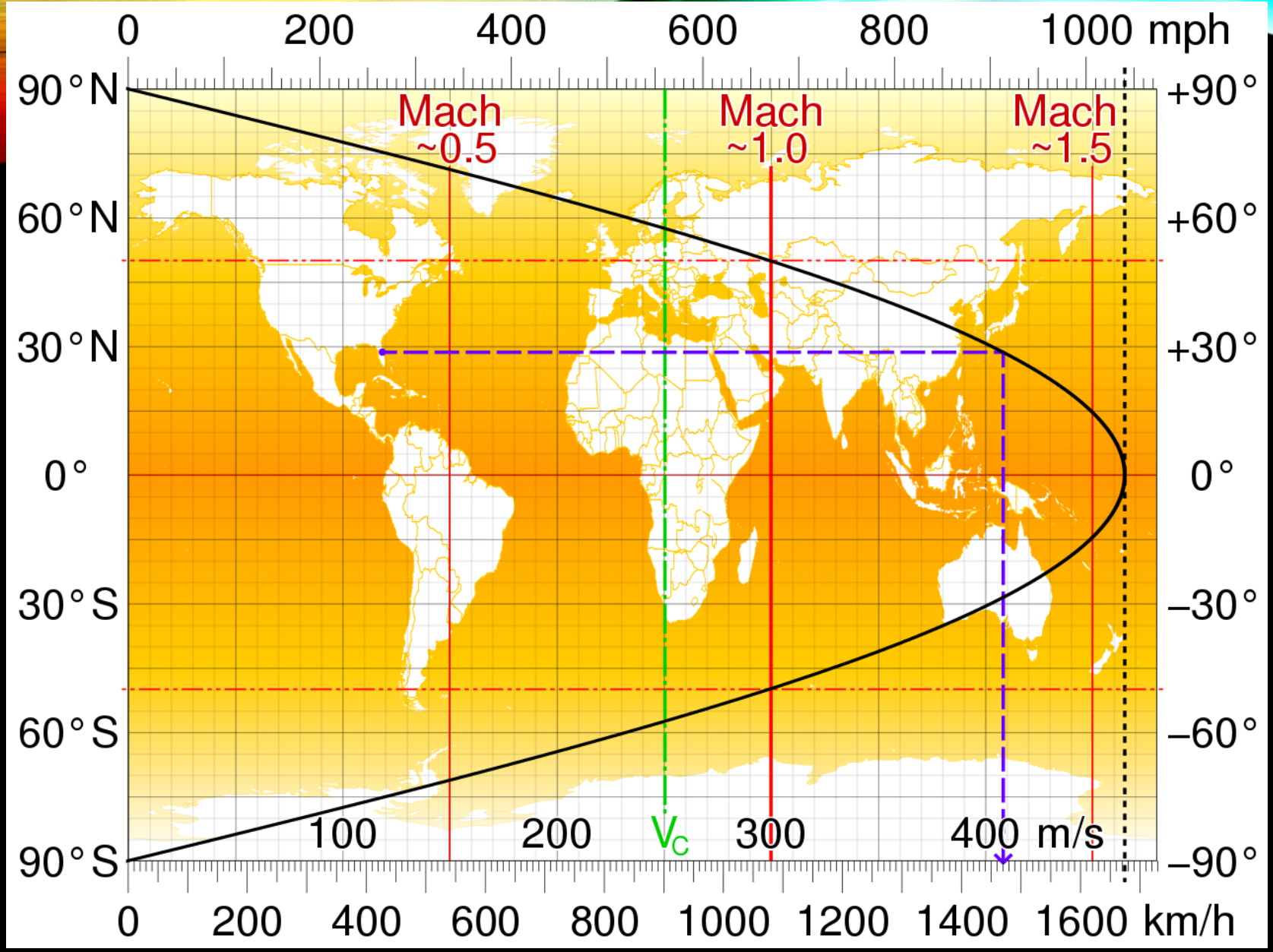


Diagram from Wikipedia

Green dashed line the typical passenger jet cruising speed

So, let's think about what happens when something (e.g a long distance arrow) is fired northwards from Melbourne - **but on our rotating, spherical planet.**

Demonstrations:

- Globe – trace a path north or south
- Globe (or record player) – with a cross
- Record player – straight line?

Both "north/south" or "east/west" directions are affected

This turns out to be the reason why the winds flow around lows and highs as they do.

What happens to the “long distance arrow” is the same when there is a pressure difference somewhere near Melbourne and air starts to move from the higher pressure to the lower. The crucial aspect is that this is happening **on our rotating, spherical planet.**

Coriolis Effect

Another way to think of it is to think of the earth turning under the winds. If you could see moving air from a fixed point in space, you would see the wind move in a straight line as the earth rotates under it.

What happens at the Equator?

Coriolis Effect (Force)

- Named after Gustave Coriolis (1792-1843) who developed the mathematics of why anything that moves across the earth without being attached to it (including a long range artillery shell) follows a curved path.
- It is proportional to the wind speed and depends on wind speed and latitude (sine (latitude))
- **Explains the first two of the "weather map rules".**

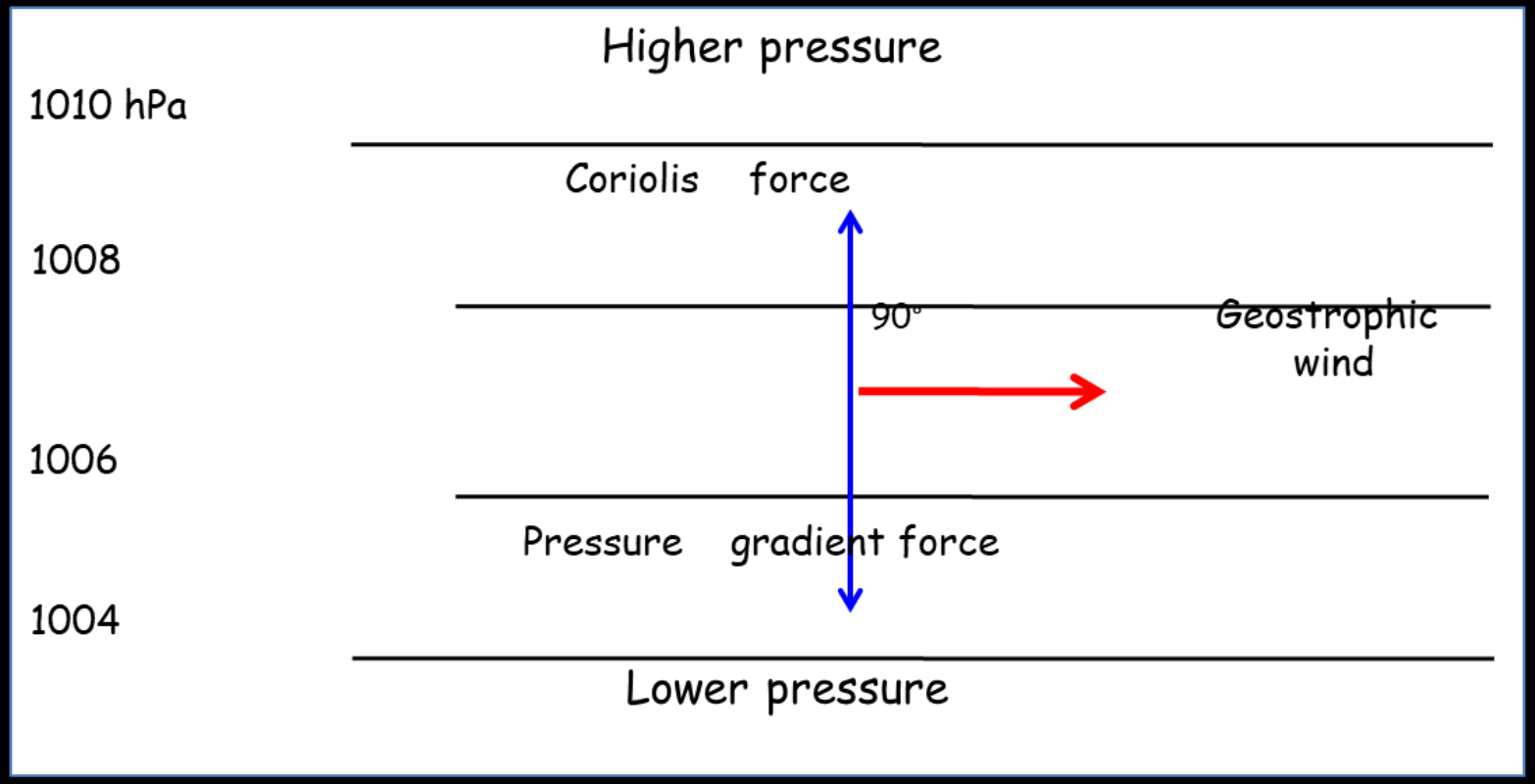


Diagram from Peter Jackson (Geology)