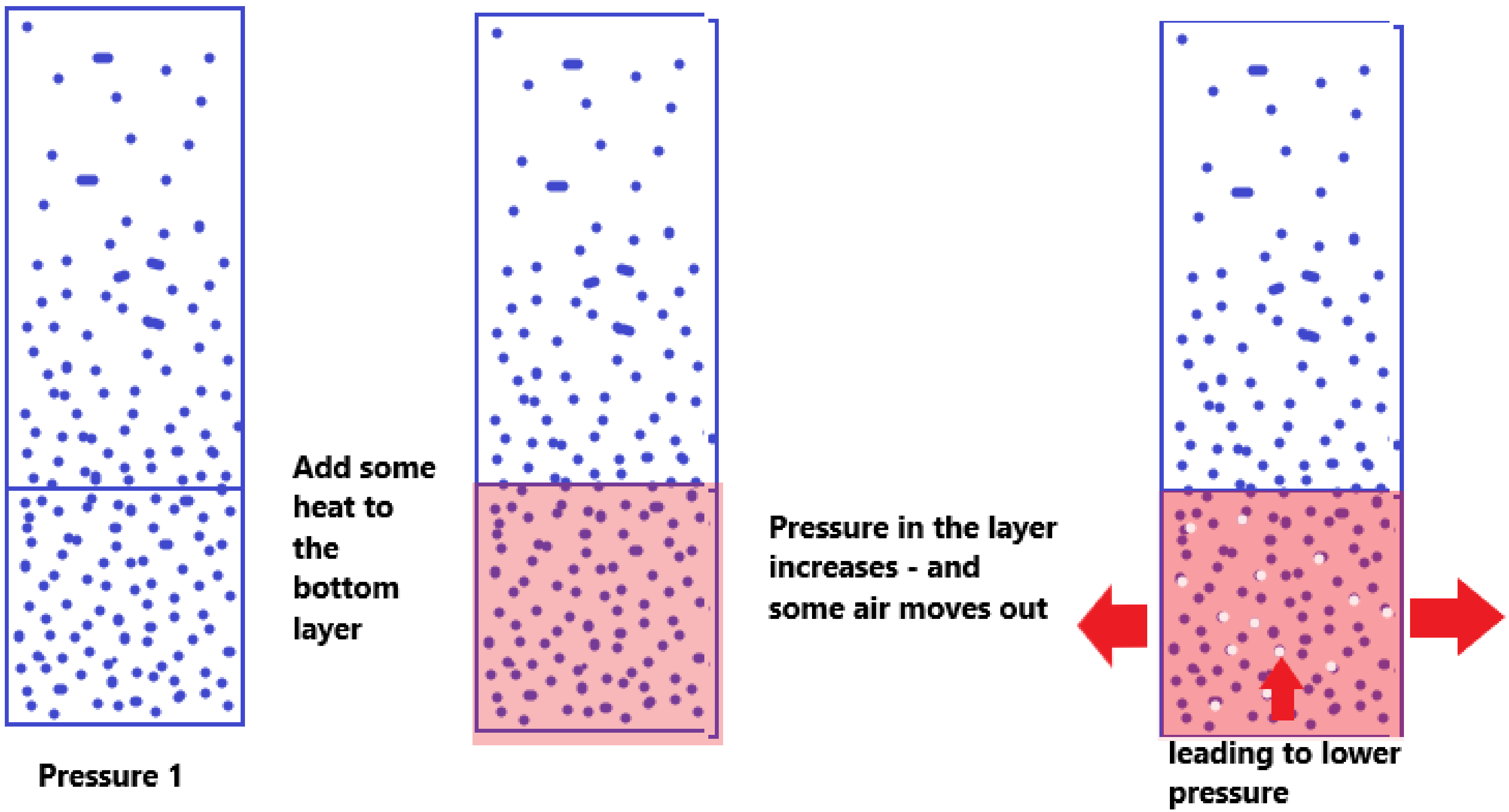
Understanding weather and the weather forecast

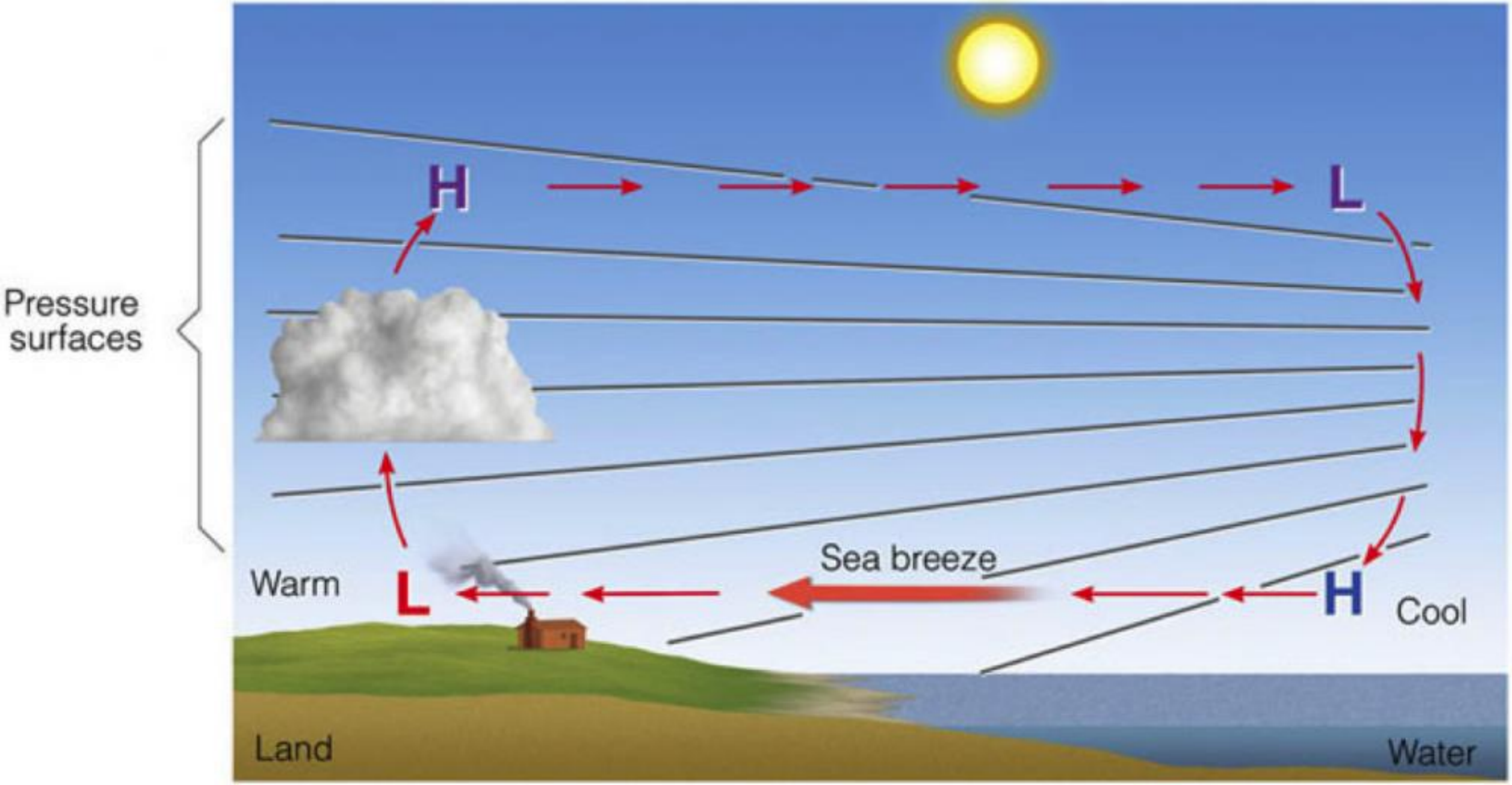
Week 5 - Coriolis Effect

Terry Hart

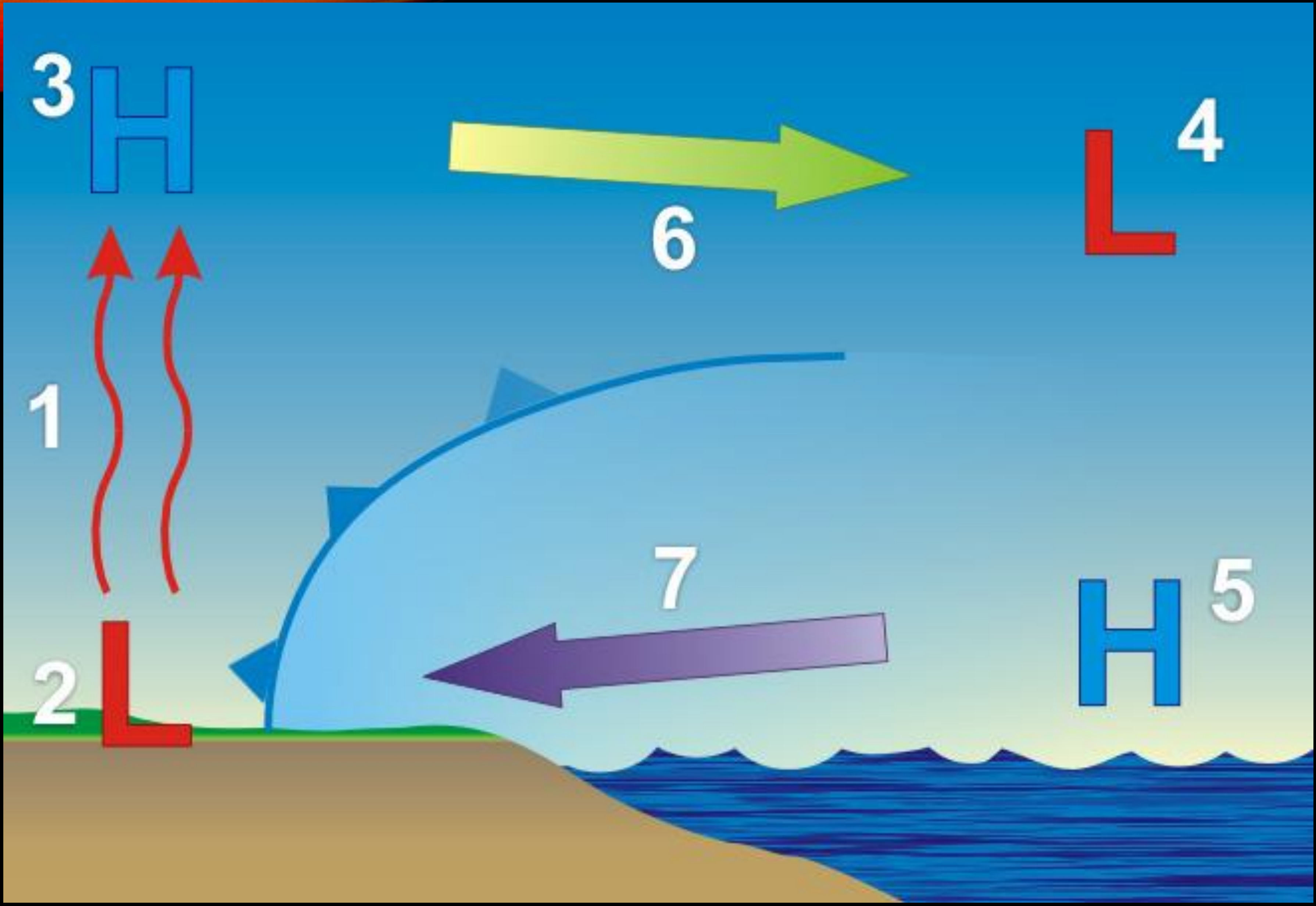
What causes the pressure to change?
And how does the atmosphere respond to differences in pressure?



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



(a) Sea breeze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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.

900 miles per hour – tangential speed of rotation?

- Is that correct?
- Is it true everywhere?

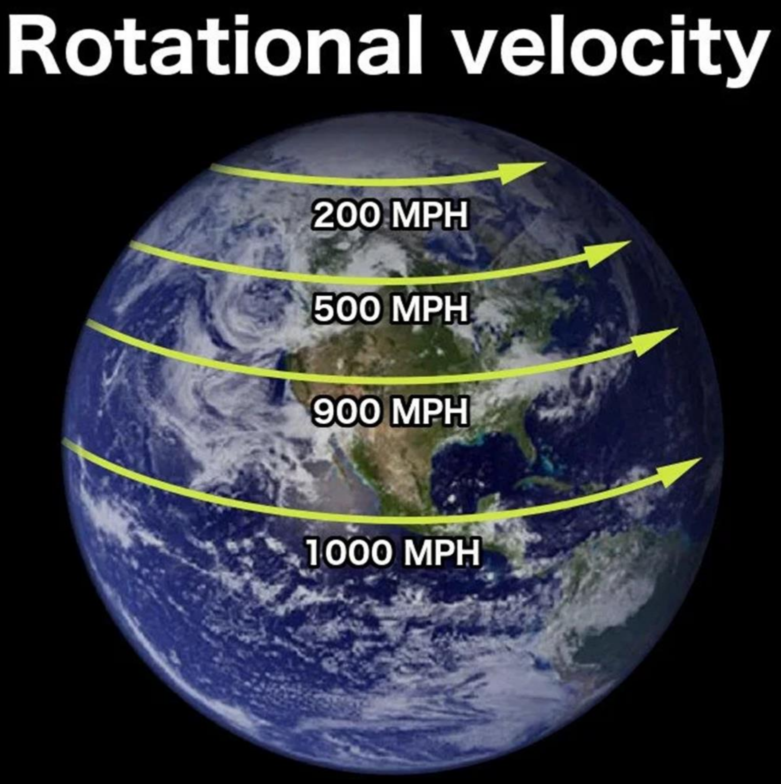
Actually **at the Equator** it is **1040 mph** (1674 km/h or 465 m/s)

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

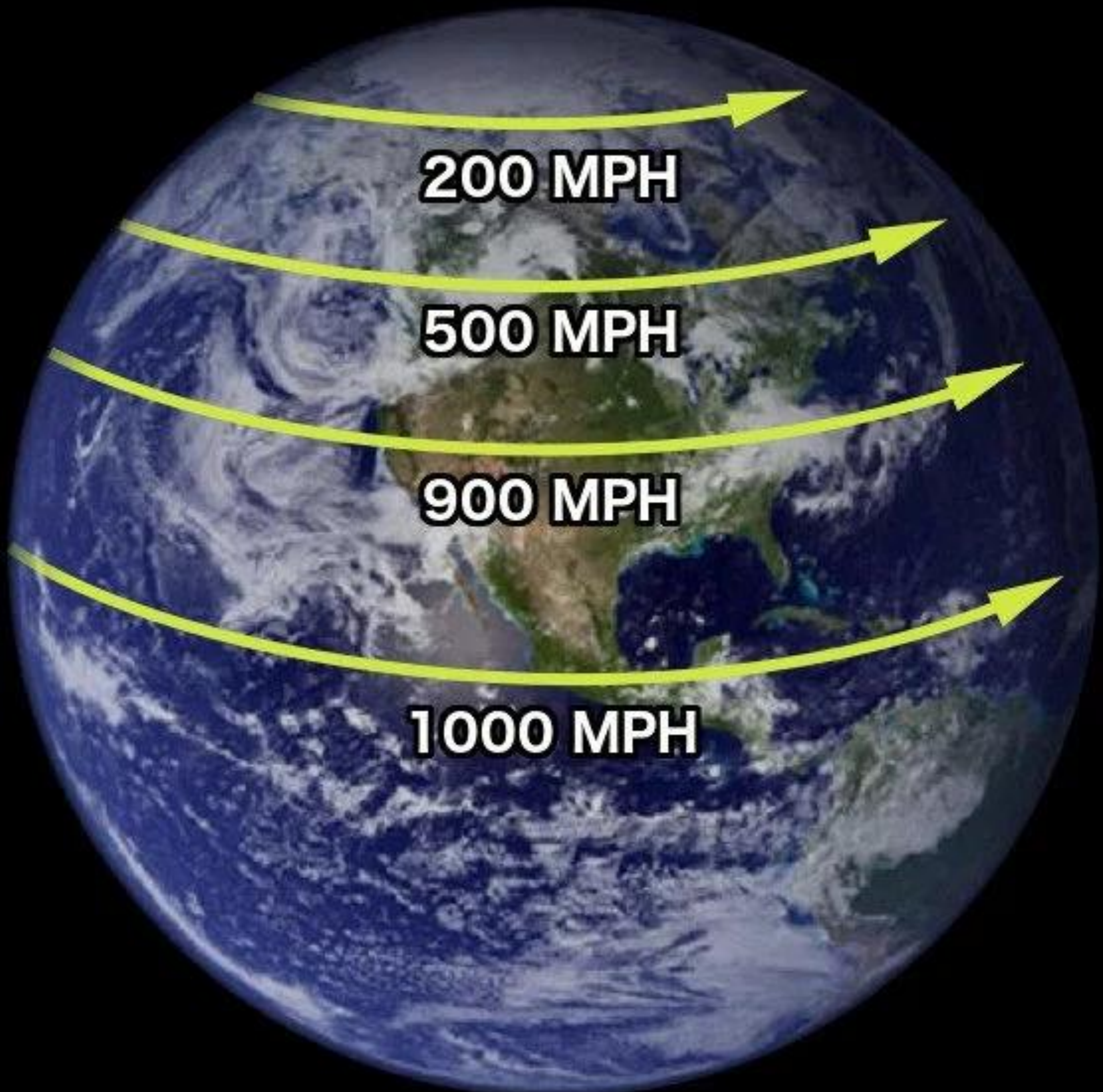
e.g. Melbourne at 38°S:

1674 x 0.788 = 1319 km/h

(819 mph)



Rotational velocity



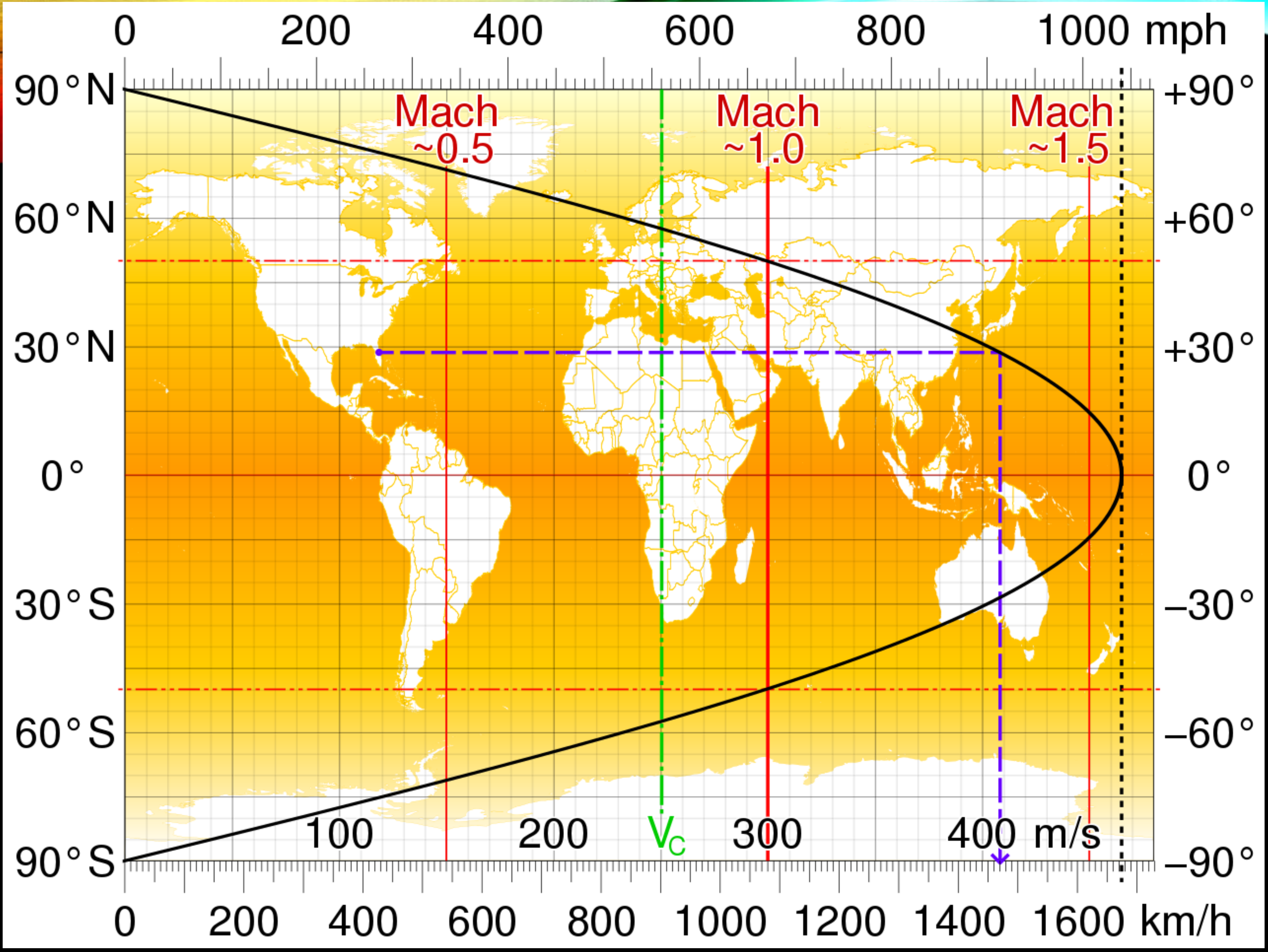


Diagram from Wikipedia

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

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".**

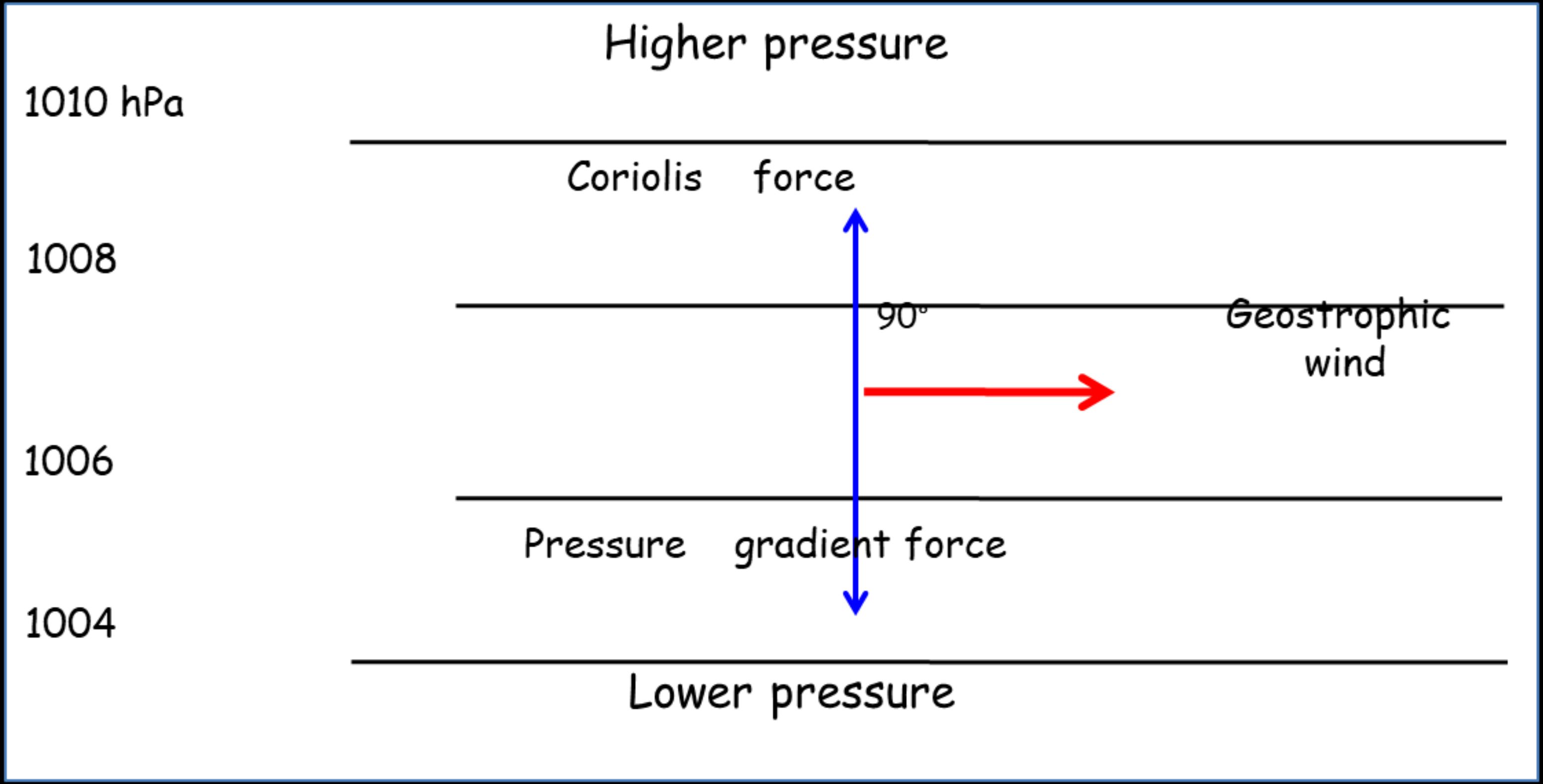


Diagram from Peter Jackson (Geology)

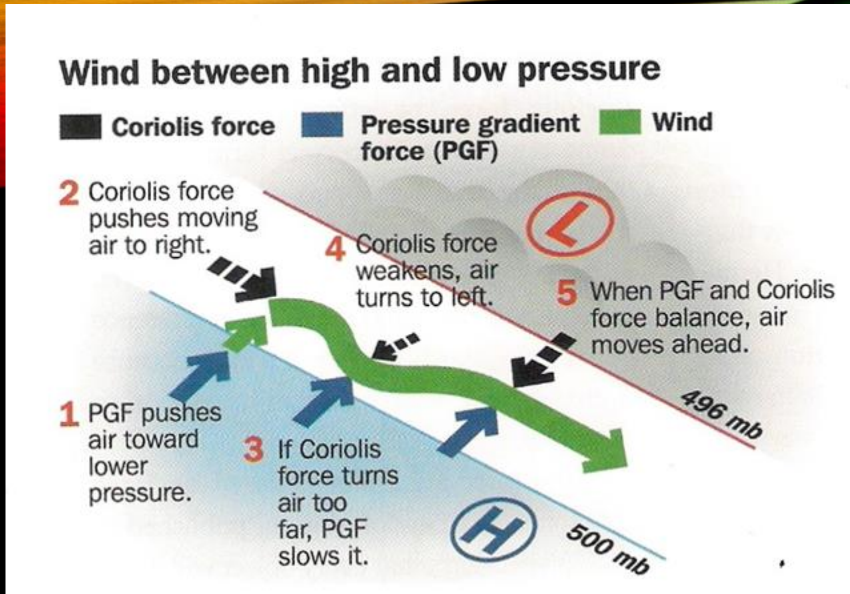
Coriolis Effect

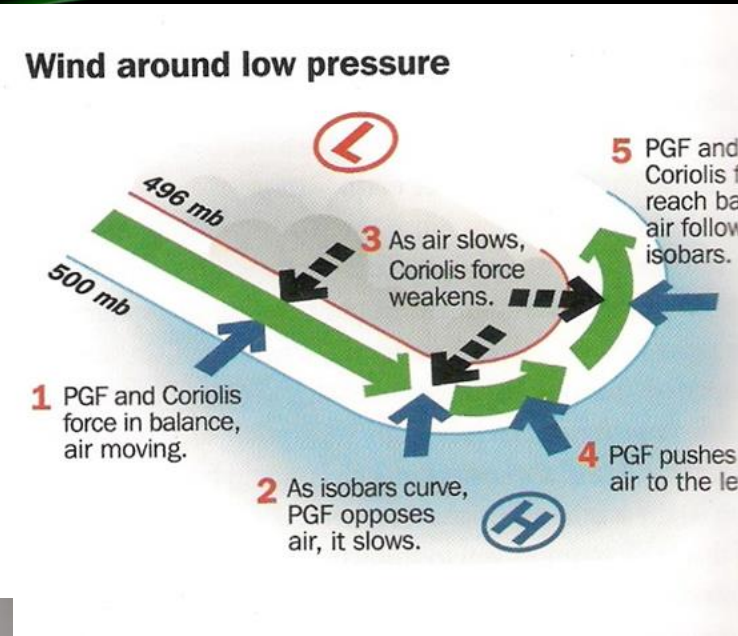
Demonstrations:

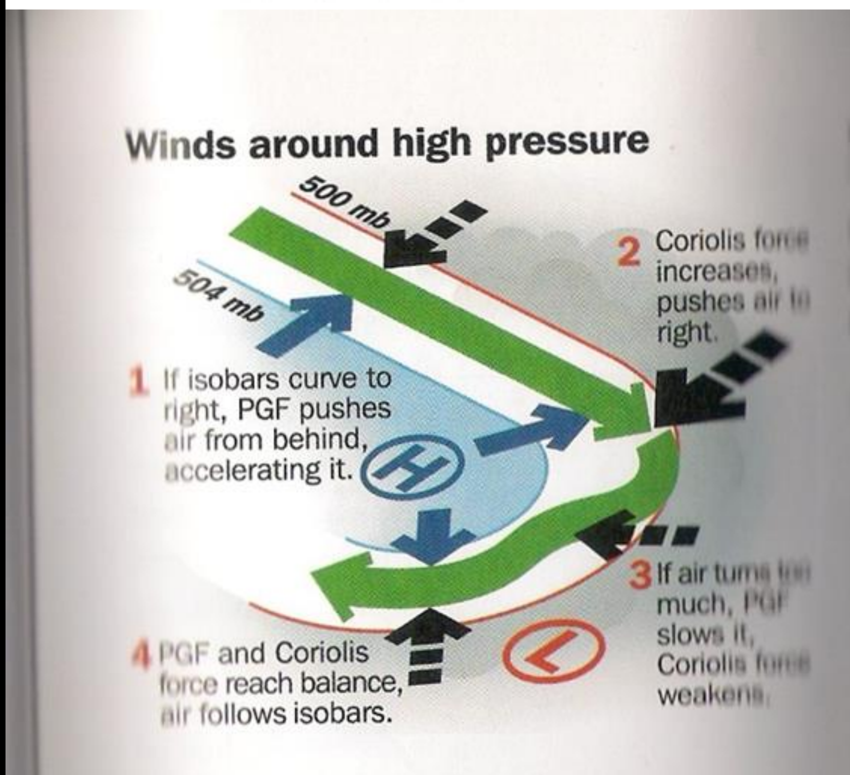
- Record player – straight line?
- Videos:

Nova - What the Physics?
https://www.youtube.com/watch?v=6L5UD240mCQ

Video – **Simply Put**
https://www.youtube.com/watch?v=HIyBpi7B-dE





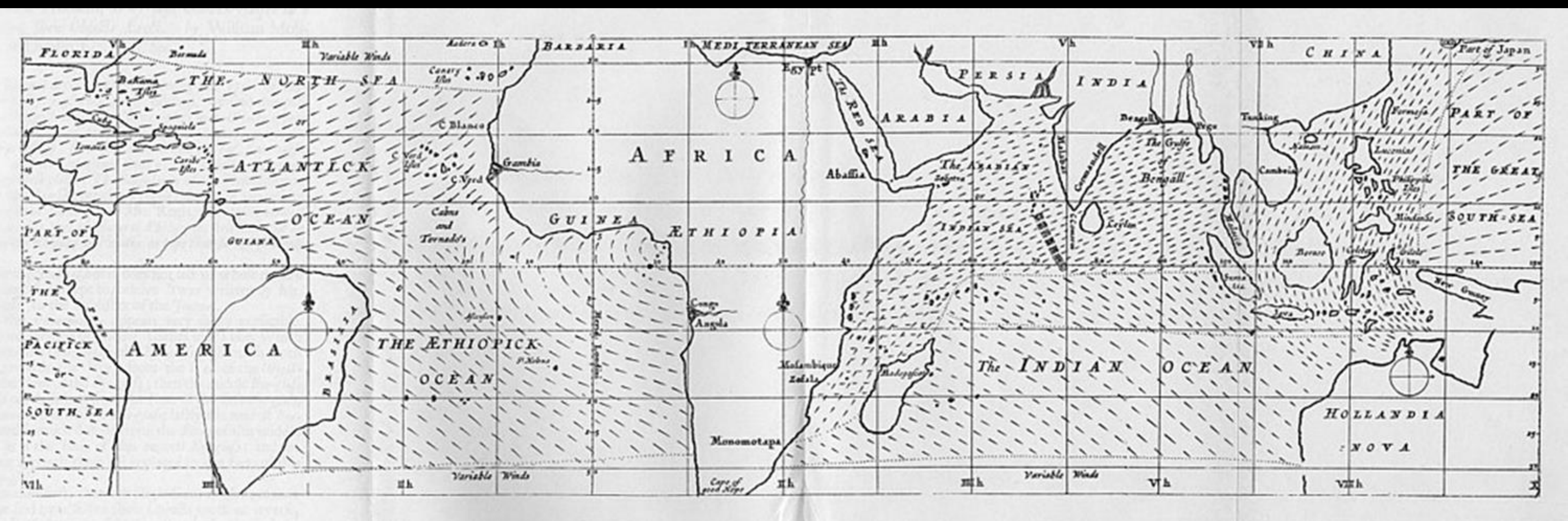


Northern hemisphere diagram!

What about winds around curved isobars?

• Trade Winds

Edmund Halley (of comet fame)
"An Historical Account of the Trade Winds, and Monsoons, Observable in the Seas between and near the Tropicks, with an Attempt to Assign the Phisical Cause of the Said Wind", published in the *Philosophical Transactions of the Royal Society* in 1686.



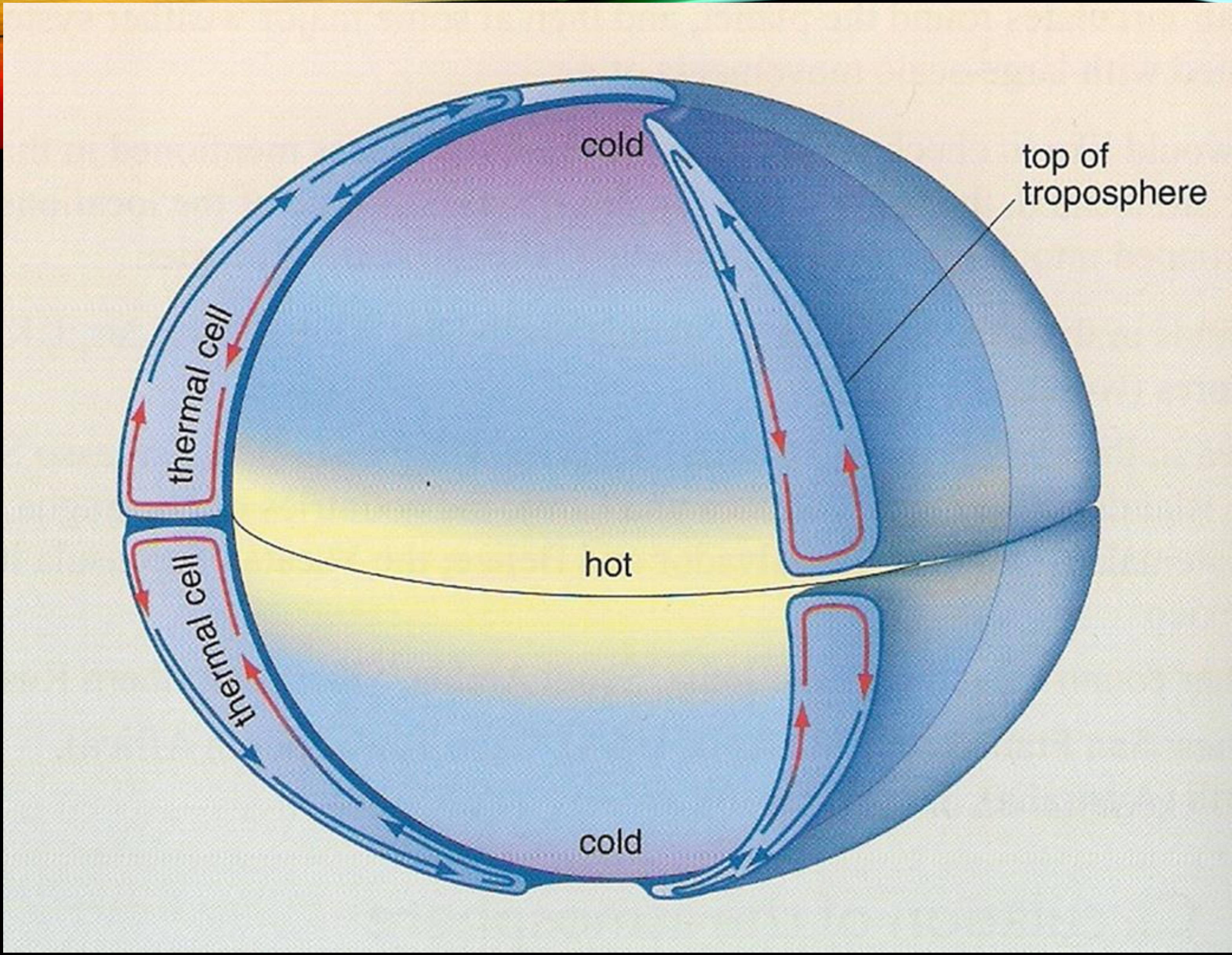
Halley proposed:

- heated air rose in the Tropics and flowed poleward, then sank as it cooled.
- with the movement of the sun across the sky – heated air is replaced by cooler air, creating NE/SE winds

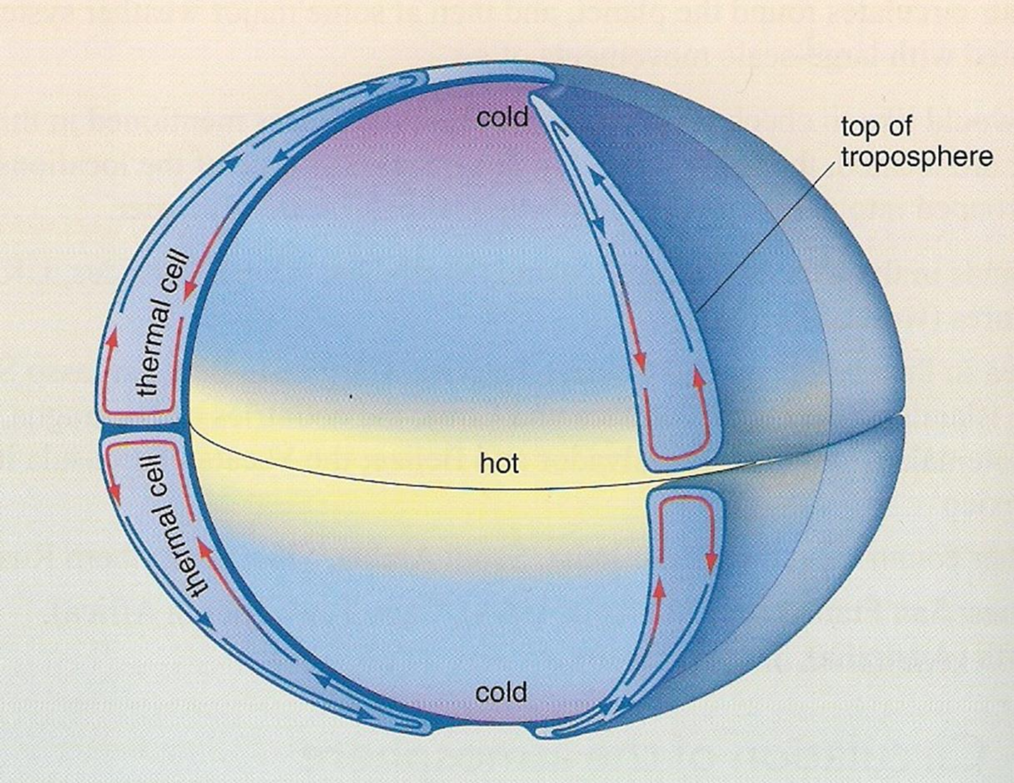
He began to doubt that when others queried it.

1735 George Hadley (lawyer and amateur student of the weather) made an important contribution.

- *He recognised the role of the rotation of the earth well before Coriolis*
- *Proposed the existence of a circulation (some decades later named the "Hadley cell")*



The early concept of the Hadley Cell

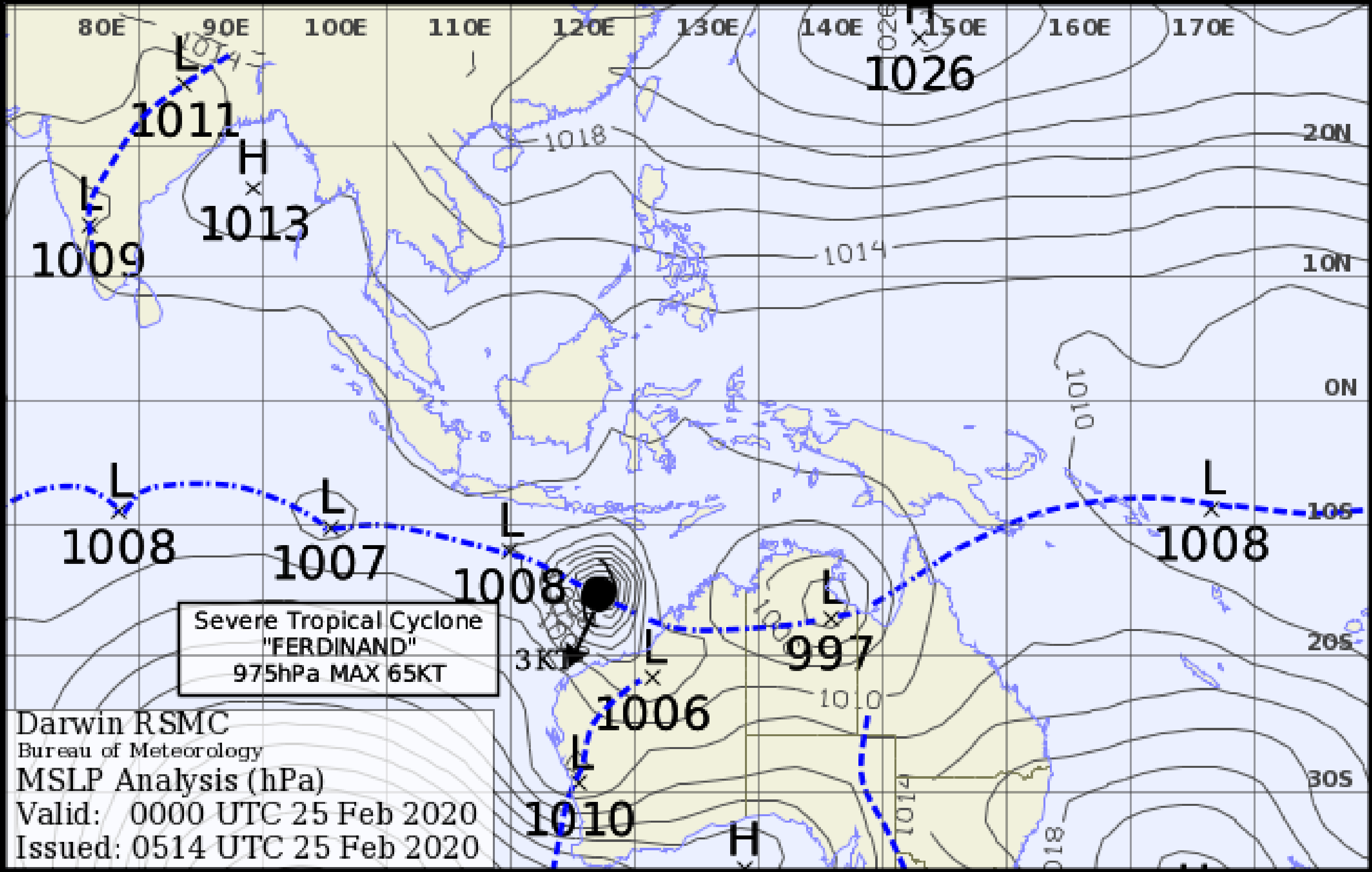


Air from more polar latitudes moves towards the Equator.
However, the rotational speed at higher latitudes is lower than at the Equator, so the air moves to the west as it moves towards the Equator (under the Coriolis Effect) giving rise to the **easterly trade winds**.

Conversely, although it was not known at the time, the upper air has to move away from the Equator toward the poles. It leads to **westerly winds** at upper levels (including the jet streams).

Some particular examples of the Coriolis Effect:

- **Trade Winds (Hadley Circulation)**
- Jet Streams
- Weather charts in deep tropics (the latitude effect)
- No tropical cyclones form at the Equator

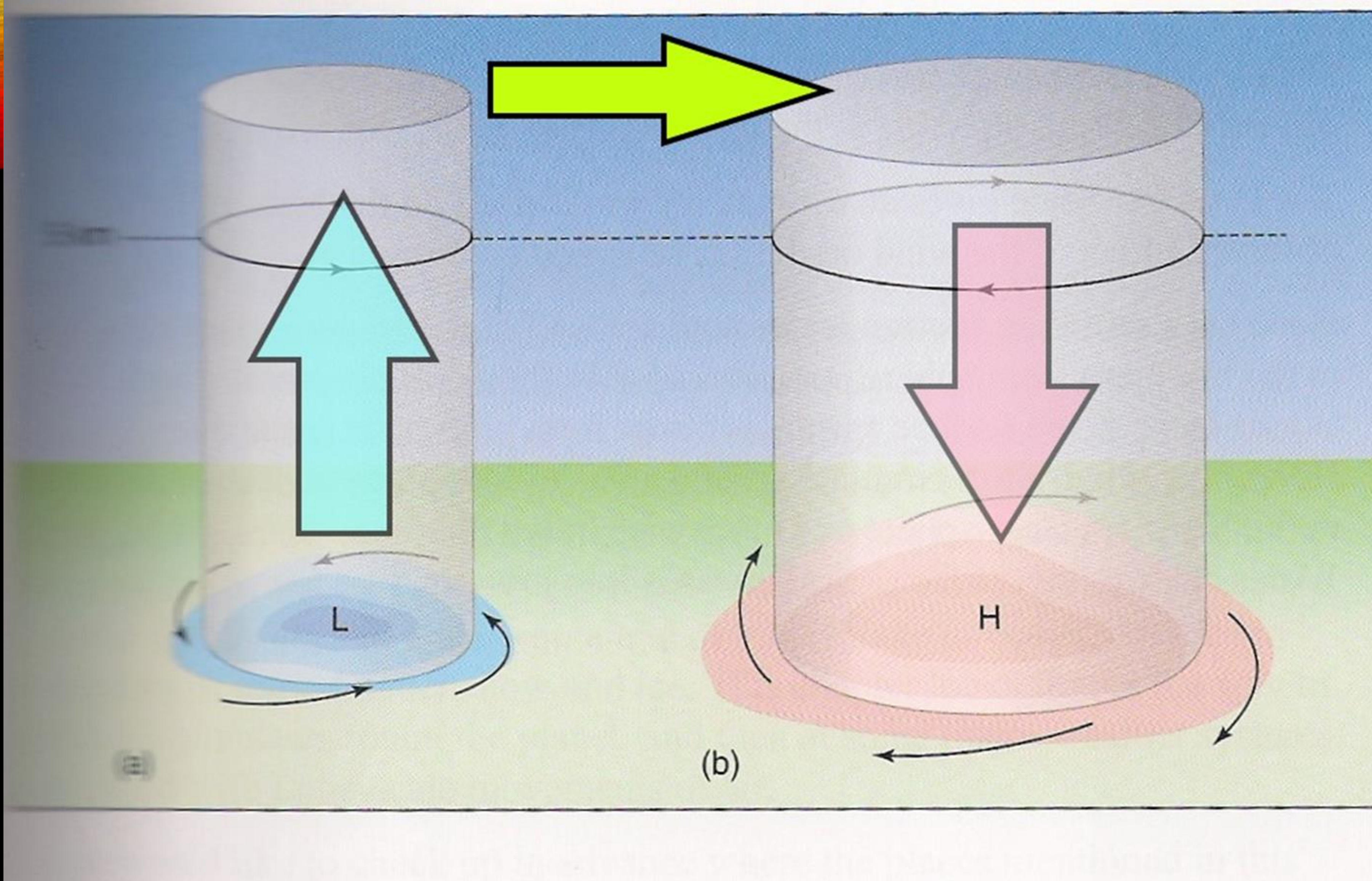


One last effect – friction near the ground

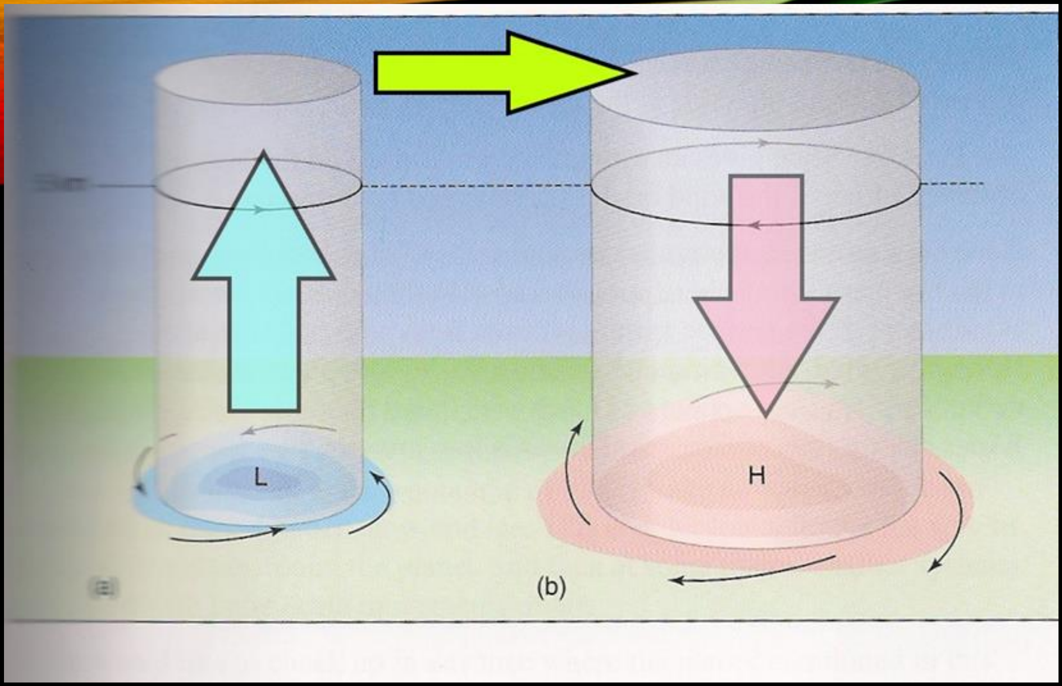
Wind is turned in towards the low pressure area – about 10 degrees over the ocean, and 30^{o} over rough land.

So in the 19th century argument over whether the wind went round the lows or went into the low, both were partly right – and it does spiral into lows.

However, there are other dynamical effects than just friction at the earth's surface.



The basis for the **third weather map rule** – rising motion leads to condensation of water vapour and eventually to precipitation (rain, snow, hail).



Rising motion leads to cooling of the air as it expands, condensation of water vapour and eventually to precipitation (rain, snow, hail).

Descending motion leads to warming and evaporation of any moisture.

Most of the world's rainforests are in the rising branch of the Hadley cell, while there are desert areas under the descending branch.