World Wide MARINE METEOROLOGY

AS APPLICABLE TO YACHTSMEN/WOMEN, AND CAPTAINS/MASTERS AT SEA

By Henton Jaaback

Deck Officer, SA Sailing and the first Southern Hemisphere MCA/RYA International Yachtmaster Instructor and Examiner.

www.sailingtrainingCD.com

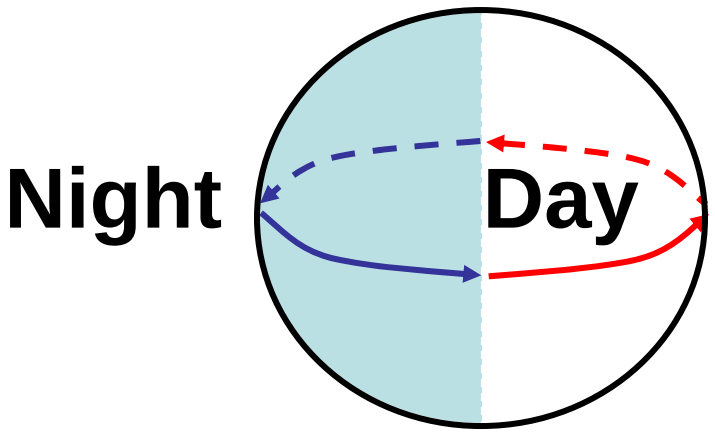
Contents

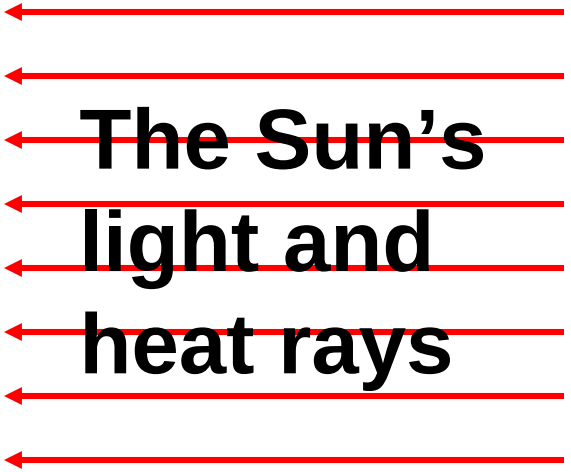
Why “Met”? What is its relevance to boats at sea?

When at sea, we are all affected by strong wind, huge waves, rain, or storms, and sailing vessels are also affected by the lack of wind. We need to know in advance if wind, and therefore sea state, is about to change – for better or for worse. We need to regularly observe the weather state, understand how changes occur, and how and where to get forecasts – *or how to make them ourselves!* So let’s start …

METEOROLOGY IS EASY!

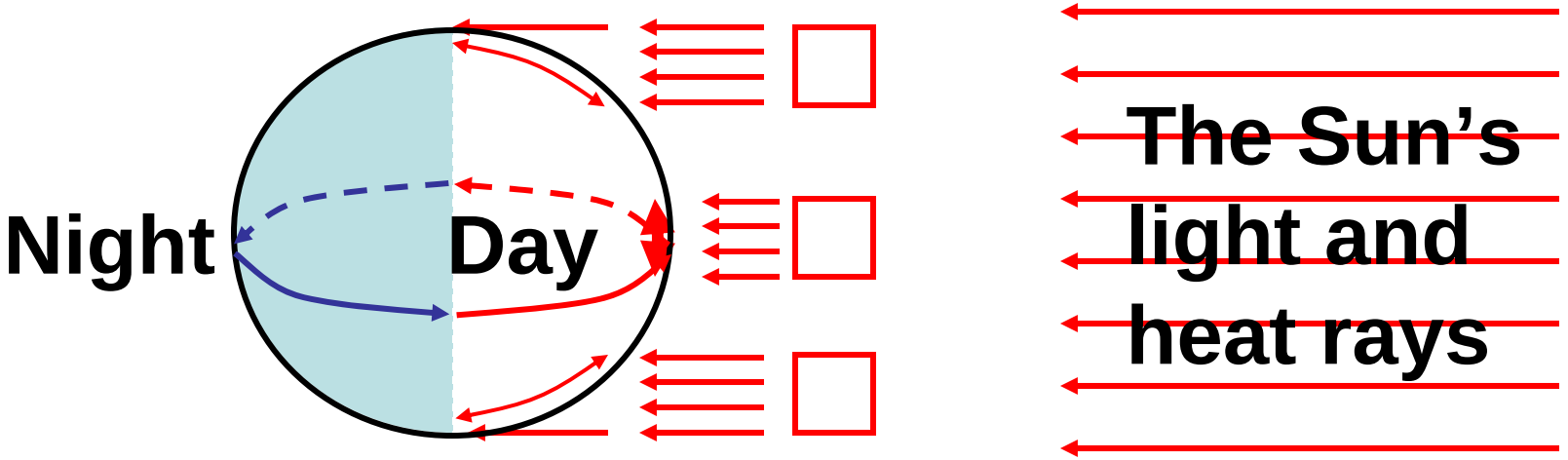
Our (round) earth is half exposed to the sun, warming up, and half is in darkness cooling down. The sun is so big and far away that the light and heat rays are effectively parallel when arriving at the earth.





WE KNOW THE EQUATOR IS HOTTEST!

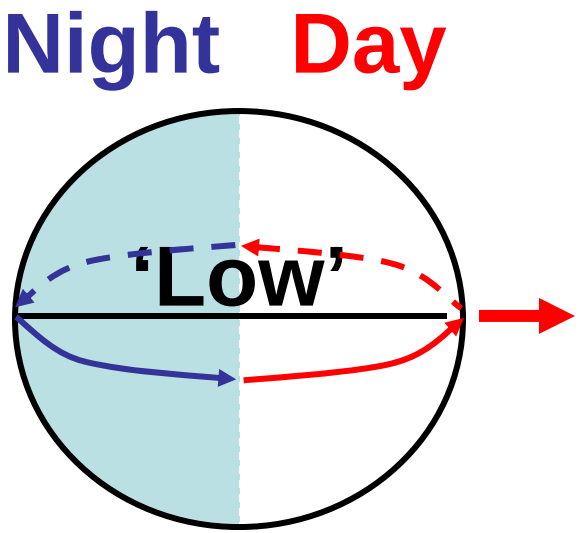
There is a greater concentration of heat rays on the earth near the equator, than at the polar regions:



At the top and bottom, north and south, the same amount of heat, □, as at the equator is spread over a much larger area – thus further from the equator, the colder!

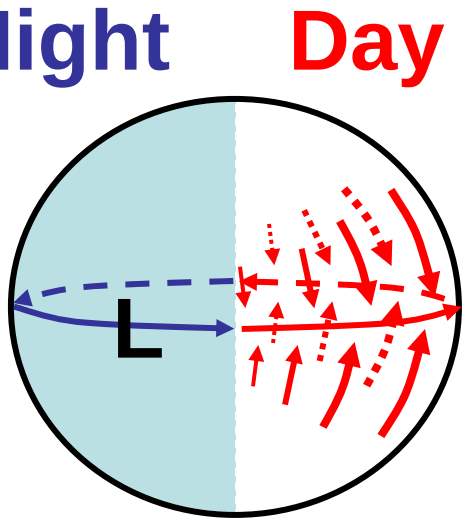
THIS IS LOGICAL!

When we see a small garden fire on a cool windless morning, we see smoke rise vertically; if windy it rises at an angle.



By day the surface air at and near the equator warms, expands, becomes lighter, and rises; the air pressure there drops – the equator becomes an area of LOW PRESSURE.

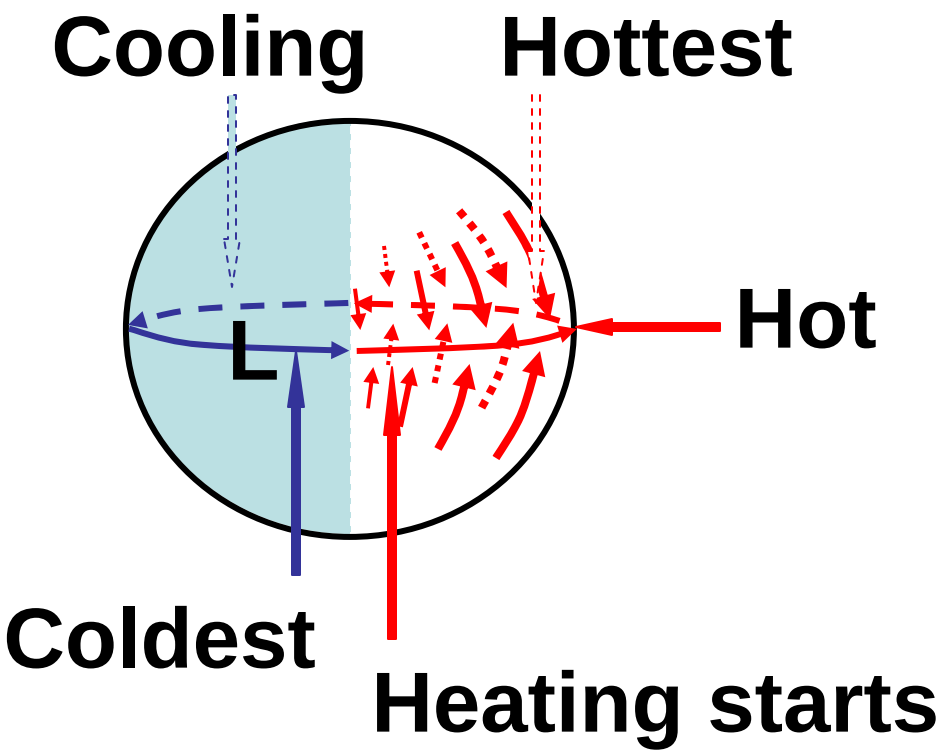
The slightly cooler, more dense, heavier air on the sides of the Low Pressure (“L”) drifts in to fill the gap created by rising, expanding warming air.



On the upper, north side the air blows down towards the south; on the lower south side the air blows up towards the north.

Day and Night Frequent Wind Changes

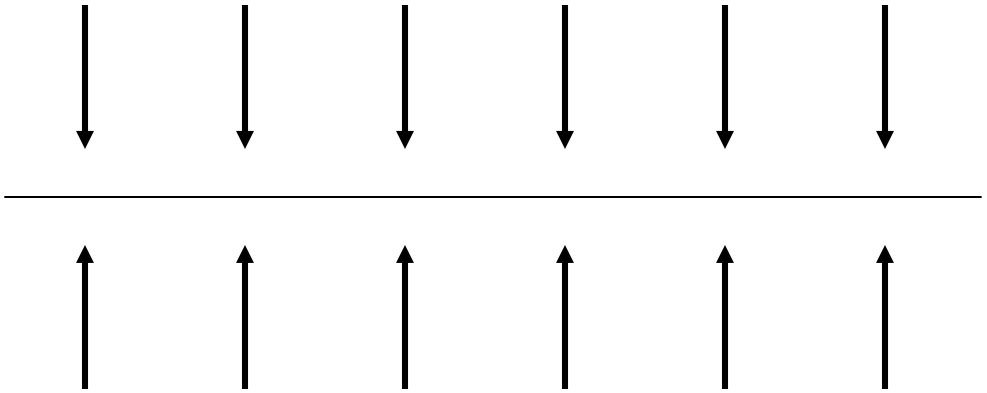
So we might as well know now why often the wind gets stronger by early afternoon, just after the mid day's hottest period …



… and slows down as the air gets coolest and heavier shortly before sunrise! Heavier air goes slower; lighter air goes faster!

So we *expect* to see the wind on both sides of the equator blow like this:

***Wind direction is described as where it comes from*; this is "Northerly" wind.**

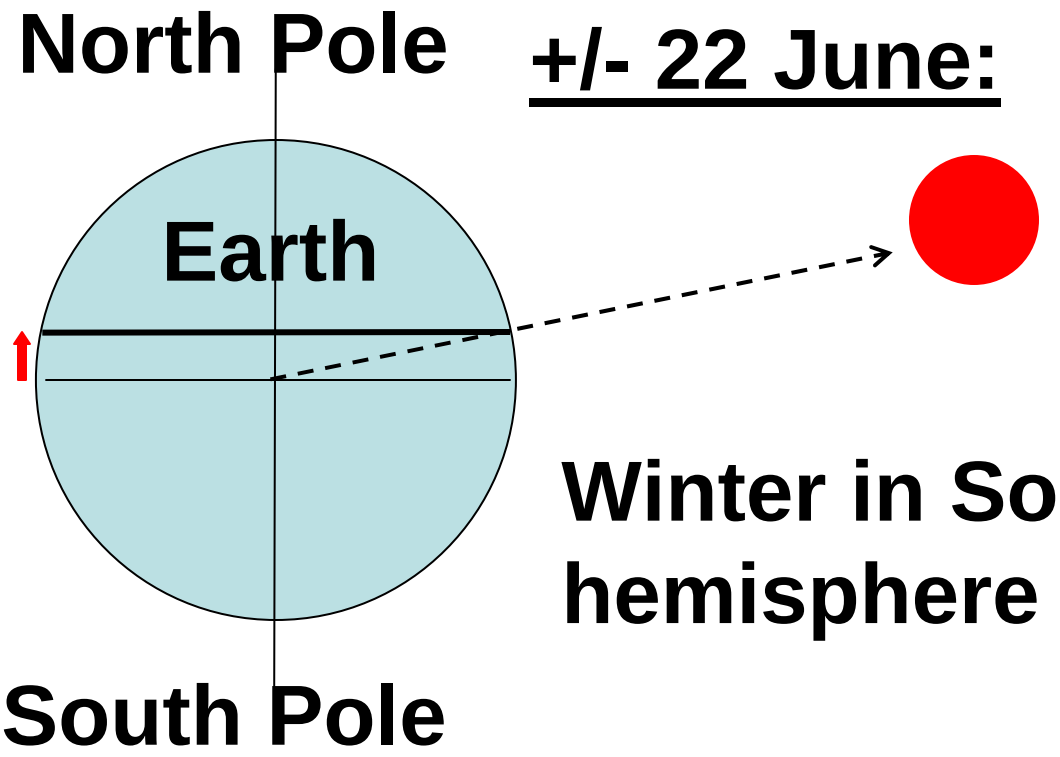


Equator (or equivalent?)

On this side the wind is coming from the south so it is "Southerly" wind. As it is from the south, it is therefore going towards the north. But be aware …

Summer and Winter changes the “Equator”

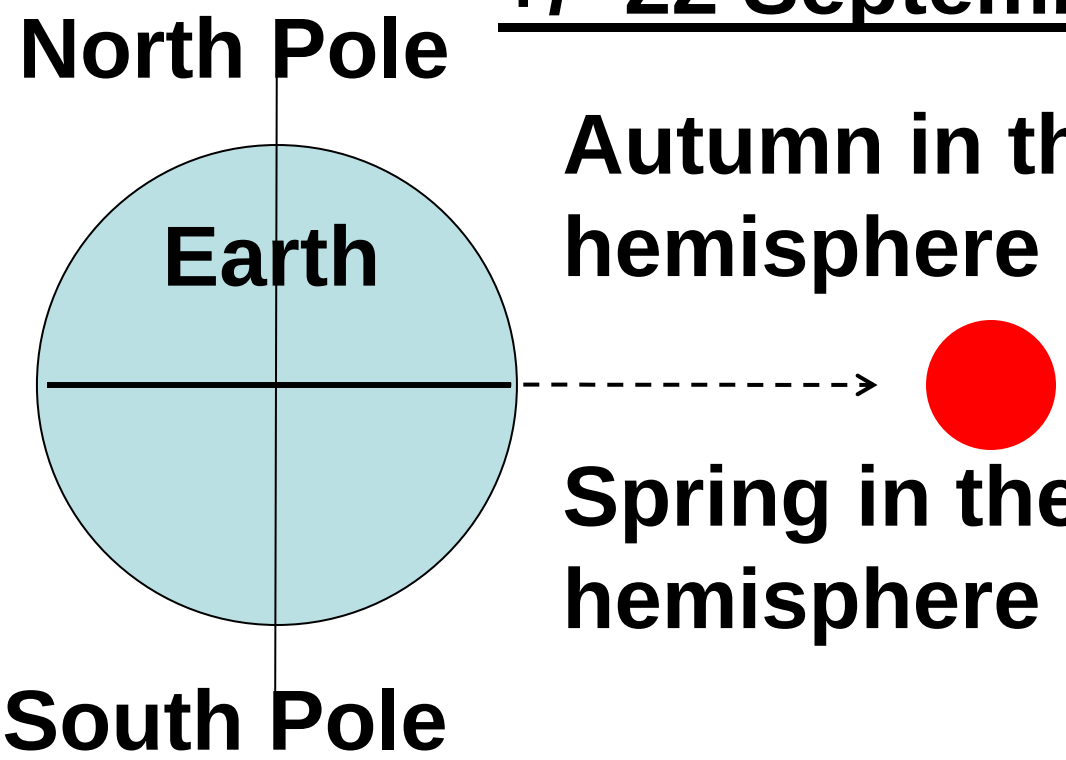
We just refer to ‘the equator’, but we mean a parallel line as it moves when the angle from the centre of the earth to the centre of the sun moves changing the seasons :



Seasons Change When the Sun becomes in Line with the Equator, Heading South

It takes 3 months to change from a maximum North angle to 0°.

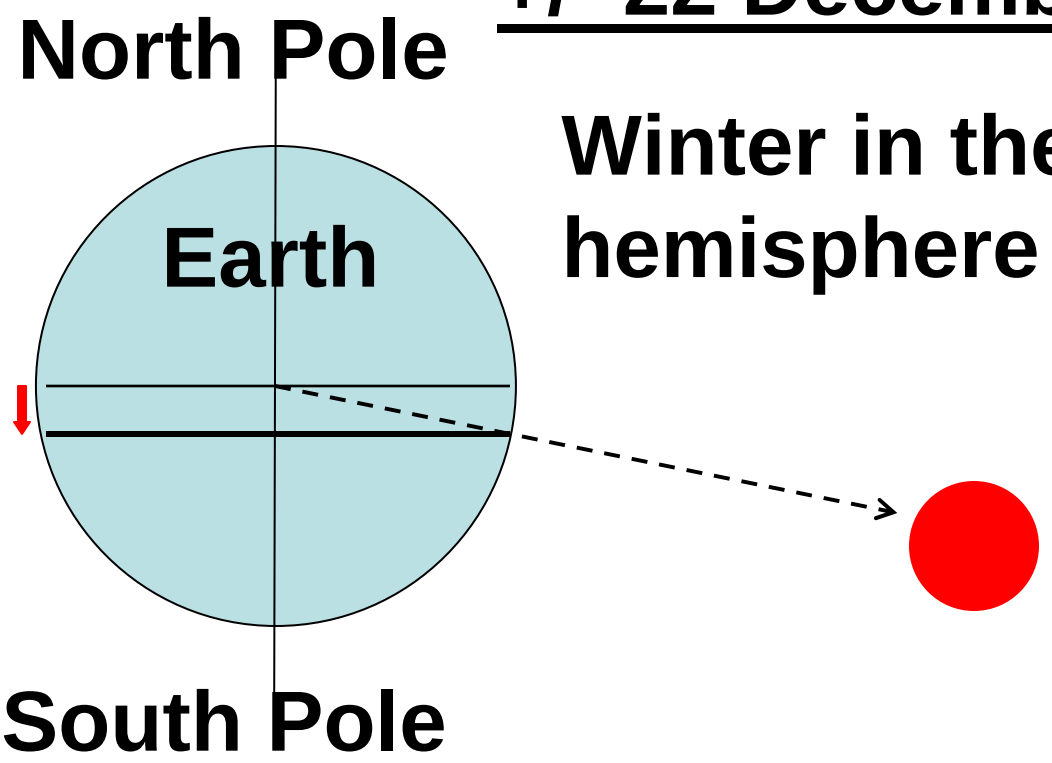
+/- 22 September:



It Changes Again When the Sun Maximum Angle is South of the Equator.

It takes another 3 months to change from a 0° to 23° S .

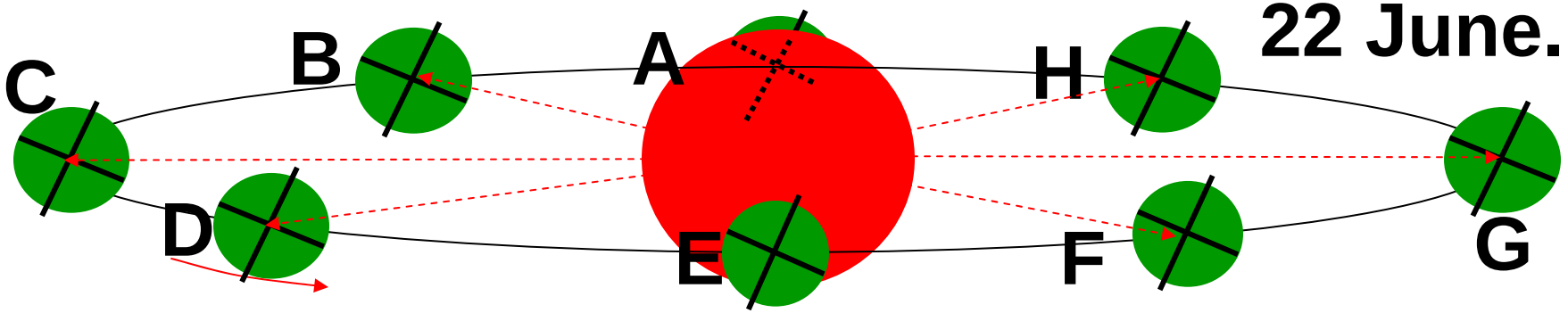
+/- 22 December:



Winter in the Northern hemisphere

Summer in the Southern hemisphere

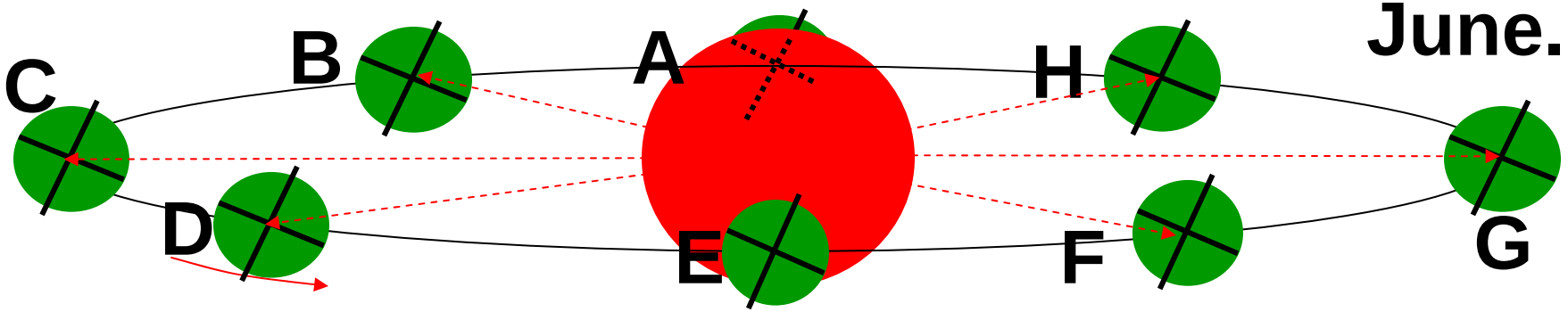
<u>Northern Hemisphere</u> seasons are when the sun direction angle, Declination, (+/- ° N/S) to the equator, and dates are: A. 0° mid Spring, +/- 22 March. B. 15°N end of Spring/start Summer, mid May. C. 23°N mid Summer, 22 June.



(The earth rotates 360° in 365 days.)

D. 15°N end Summer, mid August. E. 0° mid Autumn, 23 September. F. 15°S Winter starts, mid October. G. 23°S mid Winter, 23 December. H. 15°S Spring starts, February.

<u>Southern Hemisphere</u> seasons are when sun direction angles, Declination, (+/- ° N/S) to the equator, and dates are: A. 0° mid Autumn +/- 22 March. B. 15°N end of Autumn/start Winter, mid May. C. 23°N mid Winter, 22nd June.



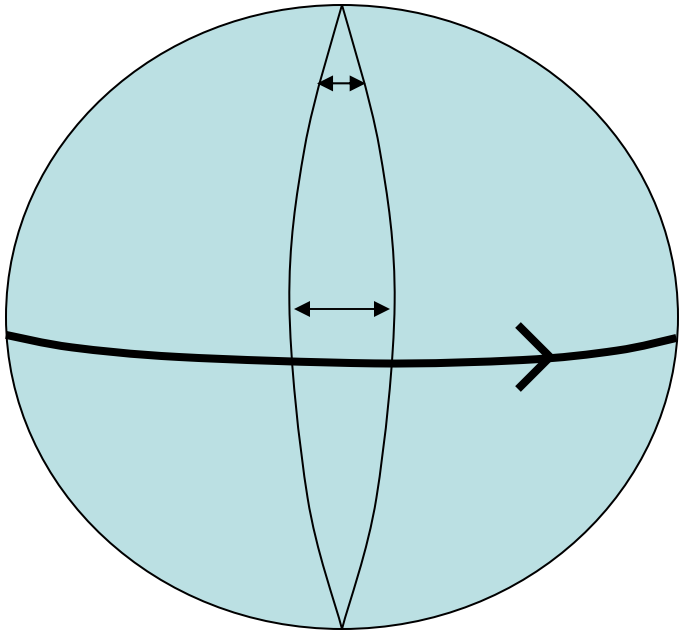
(The earth rotates 360° in 365 days.)

D. 15°N end Winter, mid August. E. 0° mid Spring, 23 September. F. 15°S Summer starts, mid October. G. 23°S mid Summer, 23 December. H. 15°S Spring starts, February.

So as seasons change, the sun's apparent movement is changing. As the direction angle, the Declination, goes northward, the Highs and cold fronts, in the north and south hemisphere's, move north - it becomes summer in the north, winter in the south. When it changes south, winter is in the north and summer in the south – there the Highs and cold fronts are further south, further away, and so it is summer.

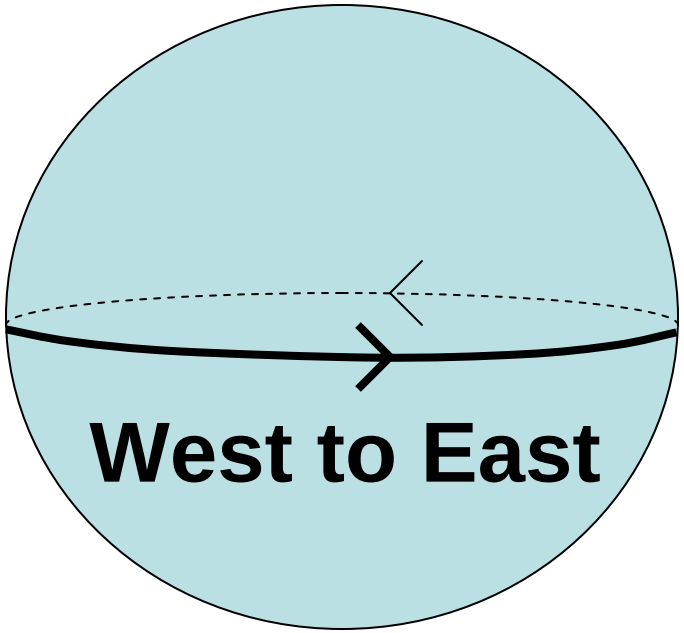
And now … <u>The Earth's Speed of Rotation</u>

We know the earth rotates 360° once every 24 hours. Each 1° has 60' (minutes); 1' is 1 n.m. (nautical mile) *at and near the equator.*



As we get further away from the equator, the same angle covers a shorter distance on the surface of the earth.

So a point on or near the equator therefore moves 21,600 n.m. in 24 hours (360 x 60 = 21,600); that is a speed of 900 n.m. per hour

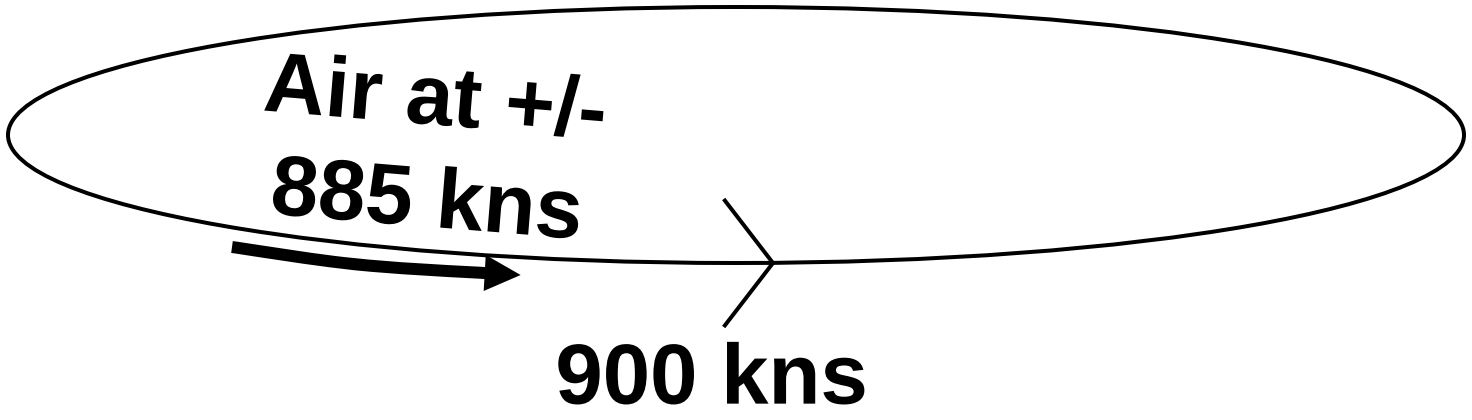


A nautical speed is 900 knots (kns) (21,600 ÷ 24 = 900).

(This speed is 1,600 km/hour*!!!*)

and … <u>The Air's Speed of Rotation</u>

As the speed of rotation at and near the equator is 900 n.m./hour (knots), the friction of the earth's surface with the air in contact with the earth causes the air to move in the same direction although it will be a little slower. The difference in speeds may average about 10 to 20 knots.

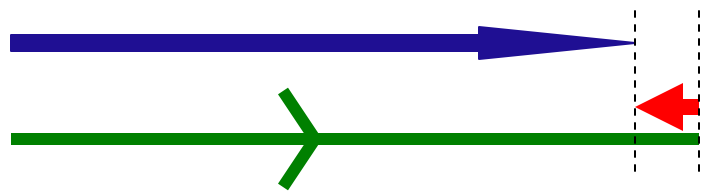


A Question:

Lets say the wind is blowing along a road at a speed of about 10 knots.

Imagine you get onto a bicycle and start to go very slowly (1 knot) with the wind. You feel it on your back. You speed up to the same wind speed and feel no wind. Now you go even faster – what wind will you experience? Answer: The faster you go the stronger the wind will be on your face!

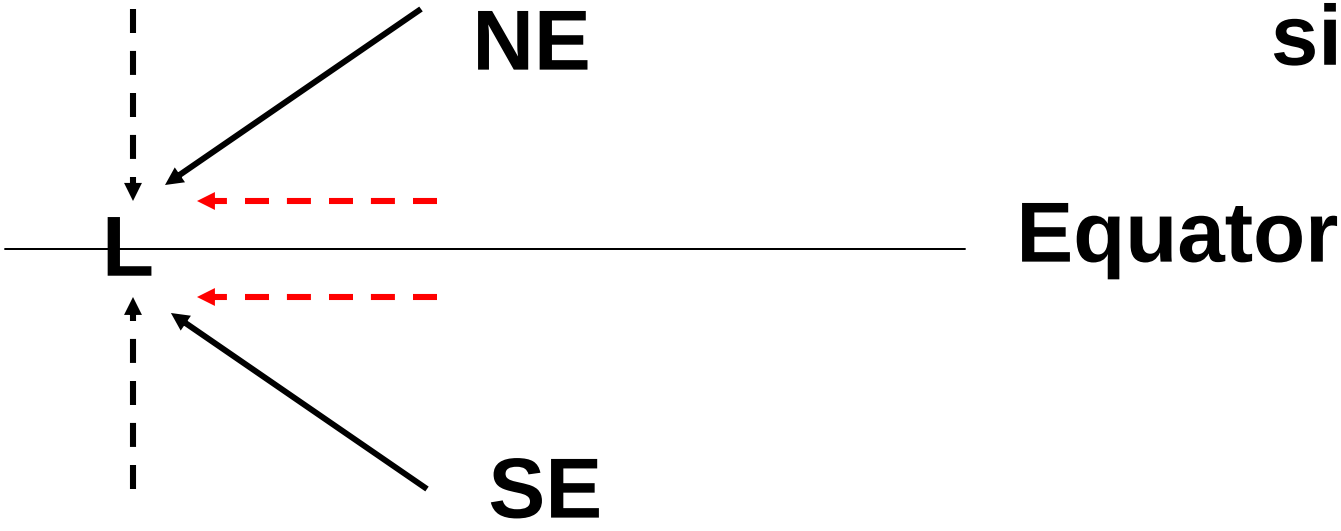
Since the earth is moving faster, we would therefore expect to experience the wind at and near the equator to be in the opposite direction to the earth's rotation, i.e. from the East going towards the west, Easterly winds, at about 10 to 20 knots.



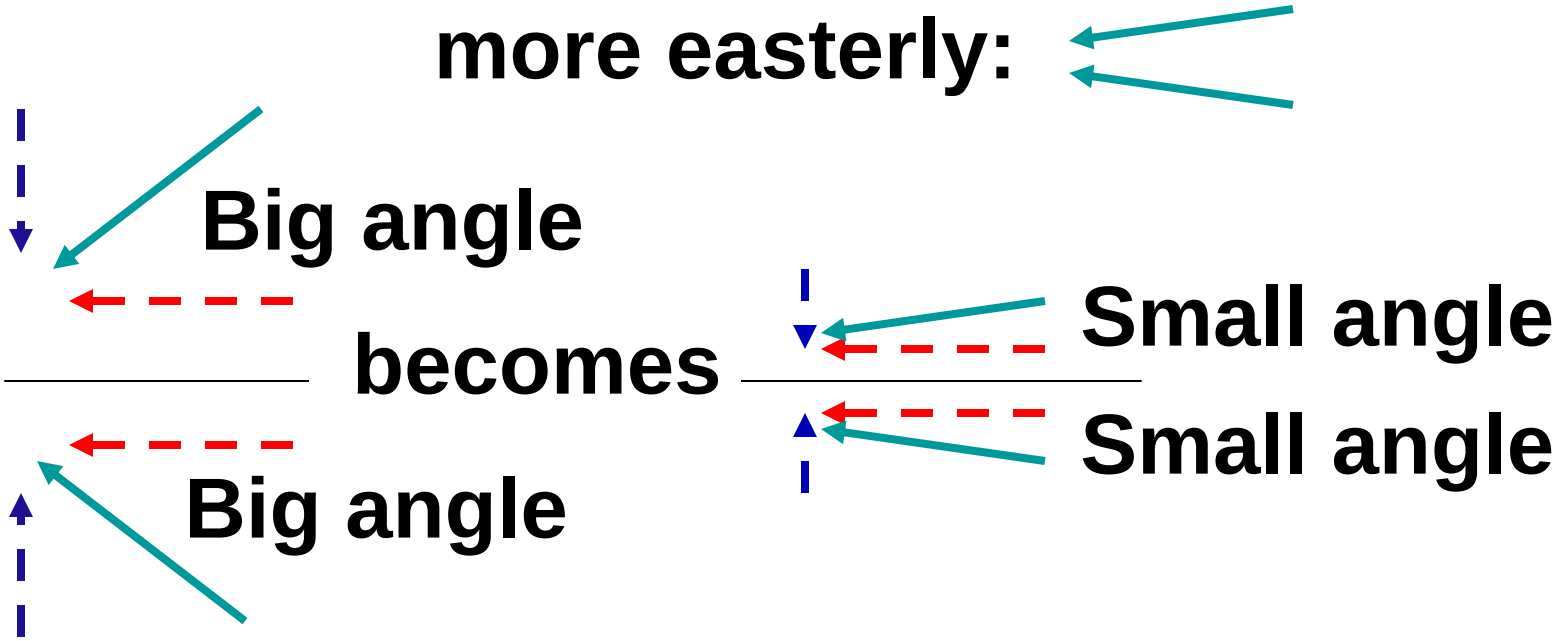
So at a fixed point near the equator the wind is *expected* to be Easterly at +/-15 kns.

So … Trade Winds

If there are northerly and southerly winds on either side of the equator being deflected by the Easterly winds, the net result is North Easterly (NE) and South Easterly (SE) winds on their respective sides.

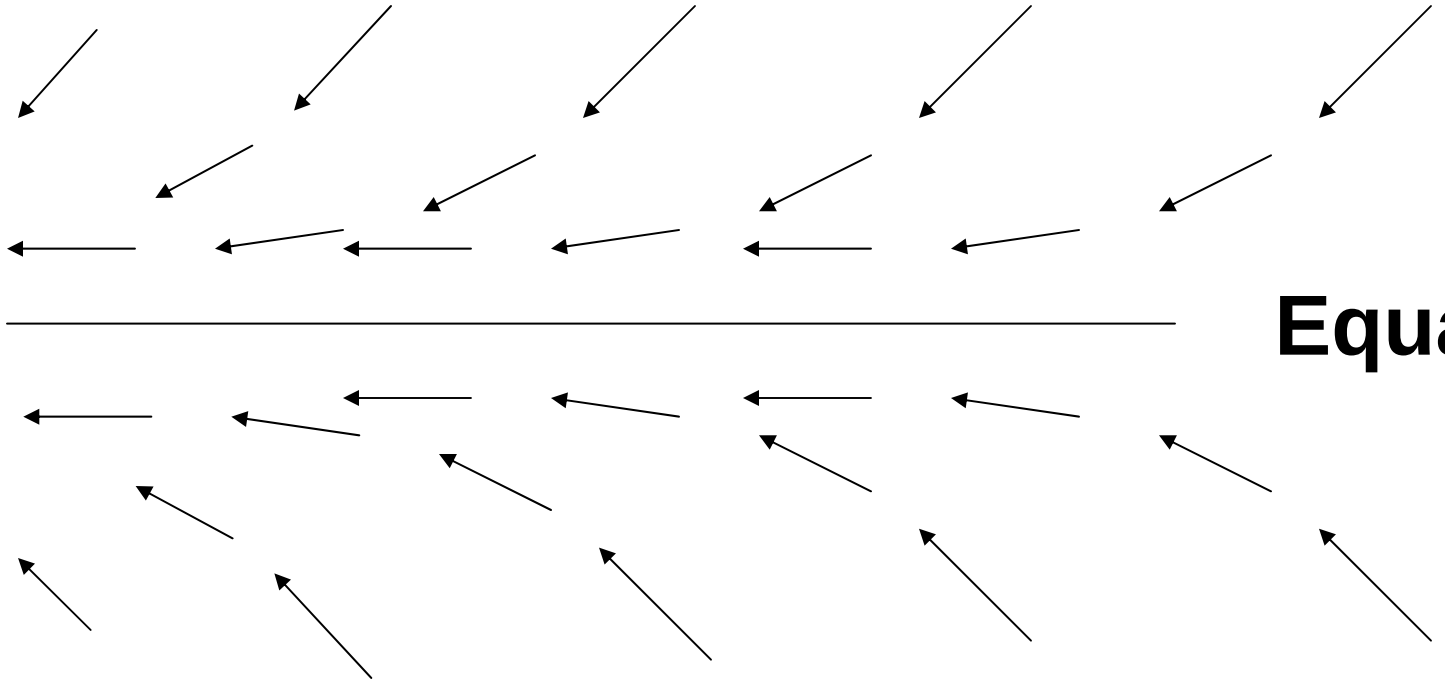


These are the Easterly TRADE WINDS – they are the same all around the equator. *The closer they get to the equator*, the northerly and southerly winds, ↕, become ↕, and therefore the easterly influence is dominant, ← - - - , so the wind becomes more easterly:



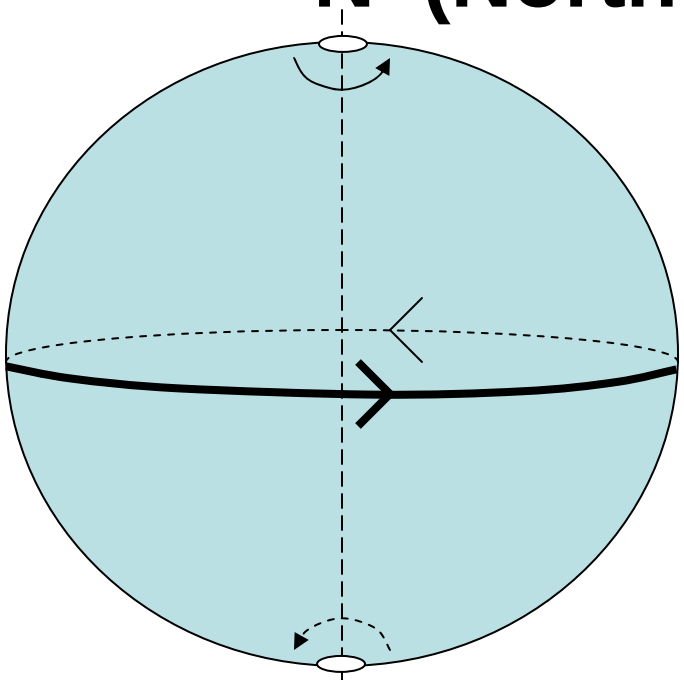
So in the area of the equator the Easterly Trade Winds blow like this:

EASTERLY TRADE WINDS



When a point on or near the equator is moving at a speed of 900 kns, can you imagine how slowly a person standing at or near the north or south pole turns once in 24 hours? VERY SLOWLY*!*

N (North Pole, polar side)

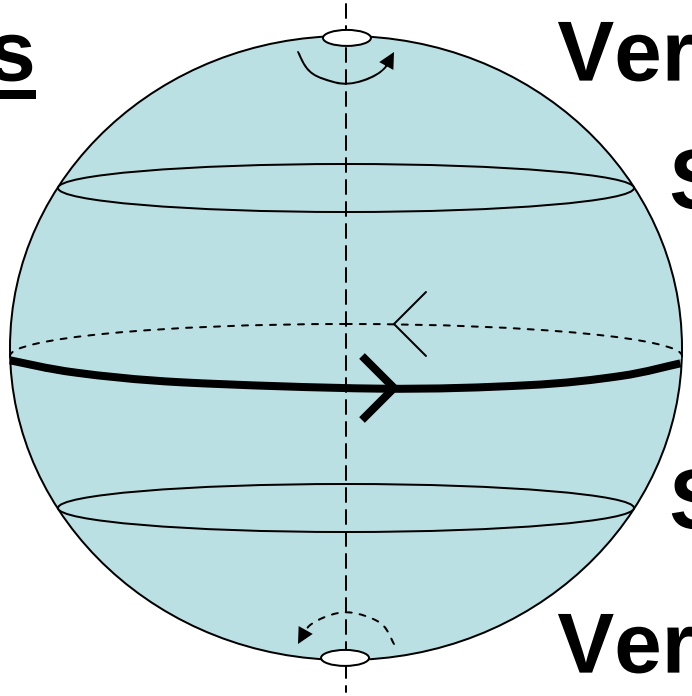


He or she has a very short circle circumference to move around in 24 hours.

S (South Pole, polar side)

The further a place is from the equator, the slower it moves – the circumference length is less than the equator but it still has 24 hours for one rotation. (Meanwhile wind speed there gets higher!)

<u>The earth's speed:</u>



Very Slow

Slower

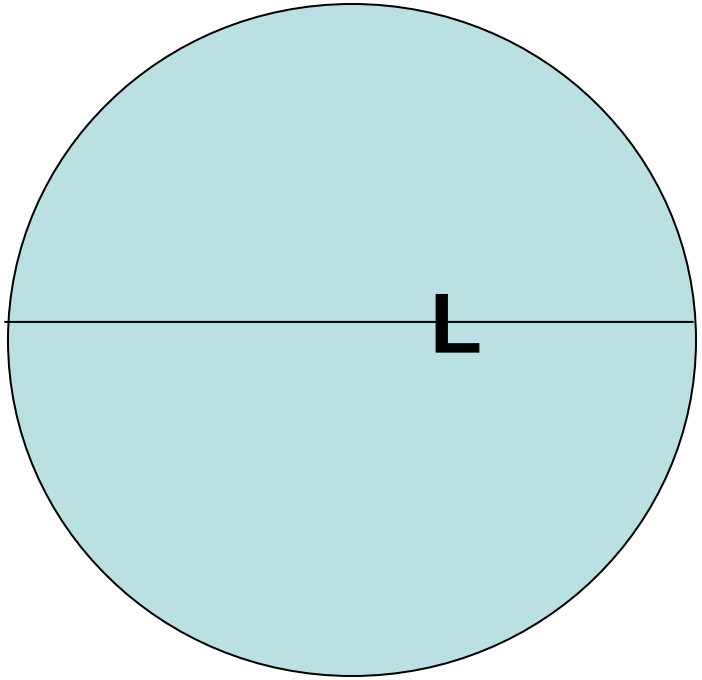
Fastest

Slower

Very Slow

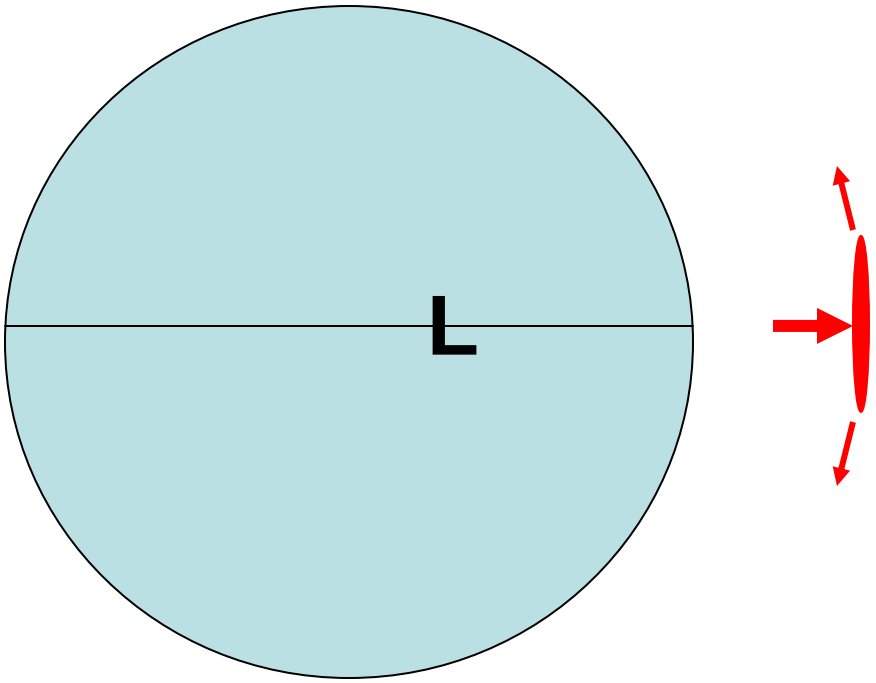
So the wind gets faster … Why?

1. As the fast (+/- 885 kns) moving hot air rises in the area of the equator, it cools. The higher it goes, the lower the pressure, the colder it gets – called ADIABATIC COOLING.



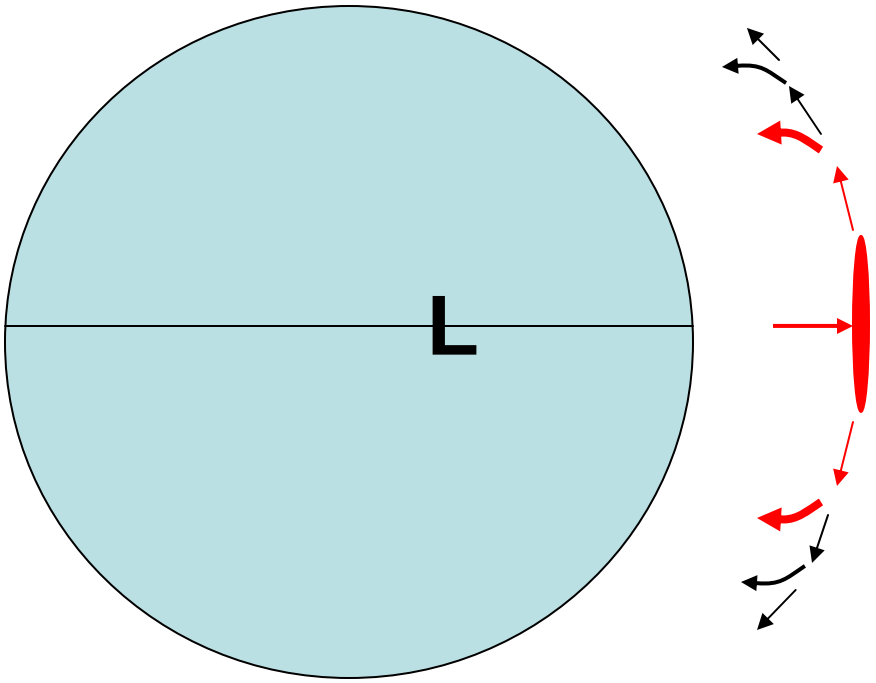
The hot air rises faster than the temperature drops. As the rising air's pressure drops, it expands.

2. When the rising air reaches the outer level of the atmosphere, it cannot move into space – it pushes and moves the rising, once warm air already there ahead of it, to the sides, to the north and south.



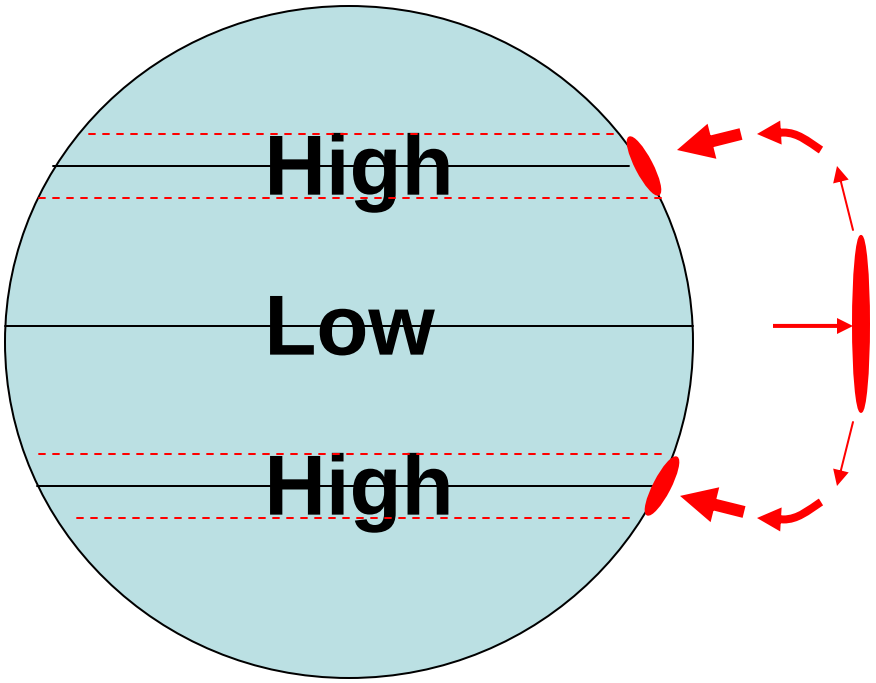
The air moving to the sides is not getting higher – the pressure is not changing (much).

3. Since the temperature drops slower than the warm air rises and its and pressure decreases, once moving sideways with no height and pressure change, the air temperature drop catches up.



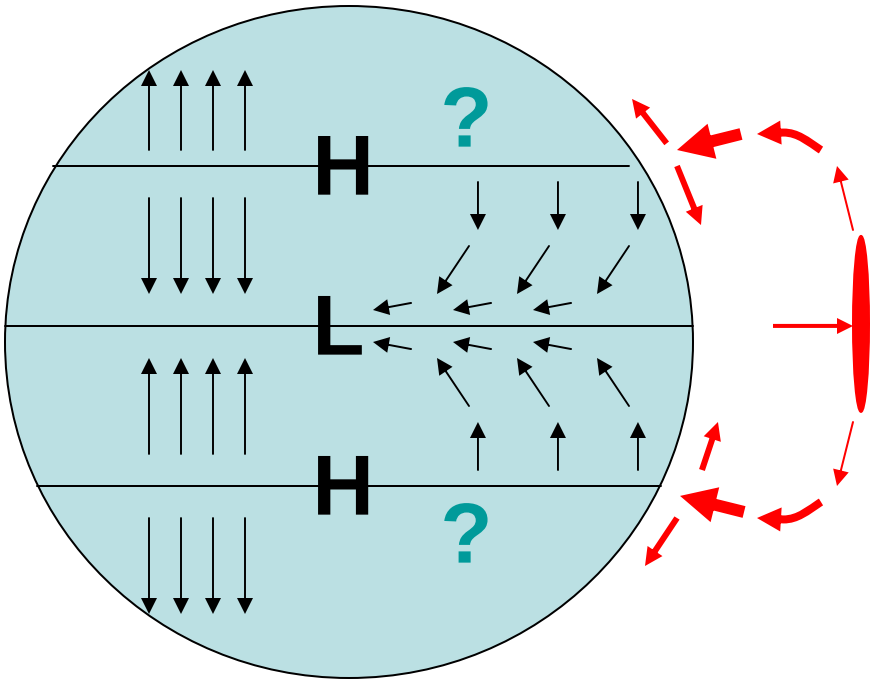
4. The air cooling moving sideways gets more dense, concentrated, and heavy. So it starts to drop.

5. As the heavier, cold air sinks down, it adds to and pushes down on the air already on the earth's surface – the surface air pressure rises. And as pressure increases, temperature increases.



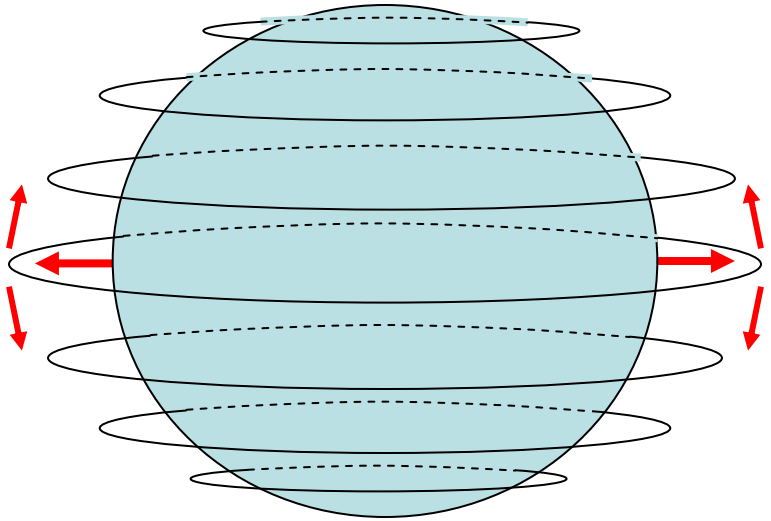
6. So on opposite sides of the Low pressure equator we see warm lines of High pressures, 'H', is created around the earth as it turns.

We expect to see the wind blows away from High pressure areas towards Low pressure areas (left), but we now know the wind adjacent to the equator is Easterly Trade Winds (right).



So what happens to the high pressure wind on the polar side of the high pressure line?

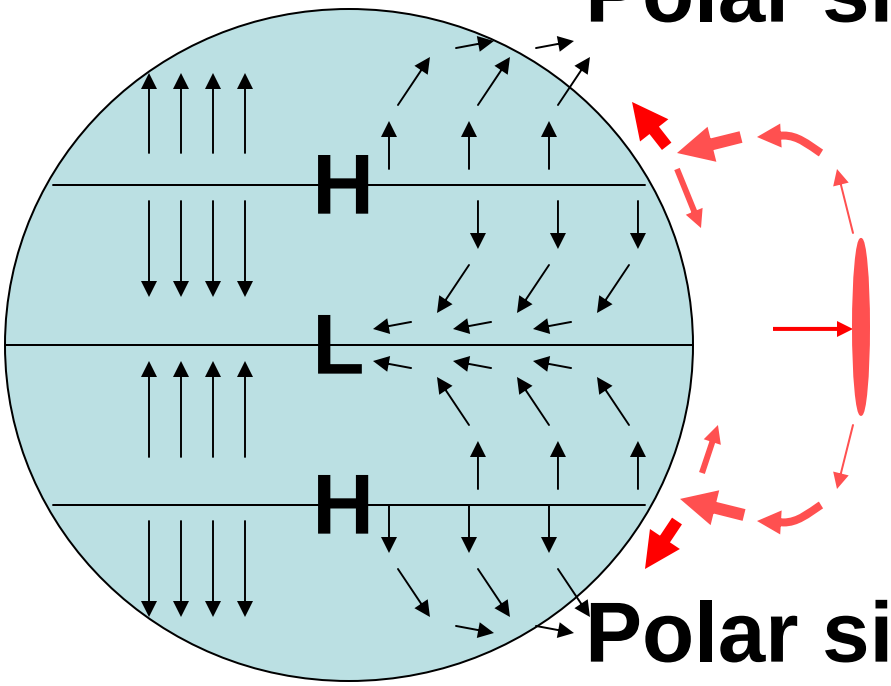
7. The wind around the equator is at a speed of +/- 885 knots. As it rises and gets pushed north or south, the circumference decreases – it has a shorter distance to go and will take less than 24 hours to go around.



8. In 24 hours, wind away from the equator moves more than once around – it goes faster than the slowing earth rotation speed.

9. <u>So that's why</u>! So we see the air, wind, on the polar side of the High pressure, H, moves faster than the earth surface at that latitude, so the polar side wind from the High, H, curves towards the east.

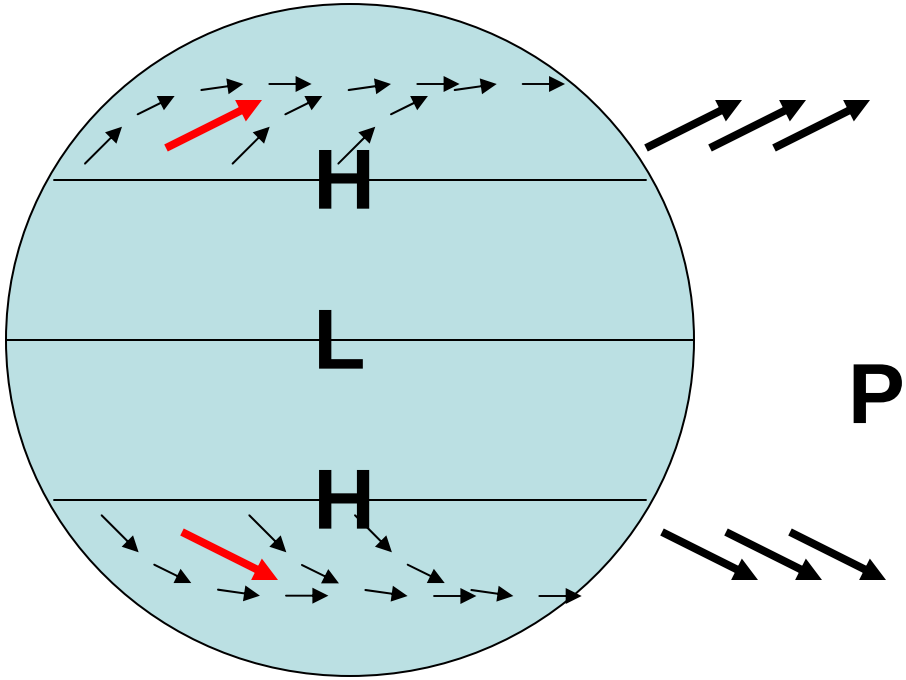
Polar side



The polar side winds are seen coming from the west (going towards the east).

Polar side

So now we see where the Westerly Trade Winds are!



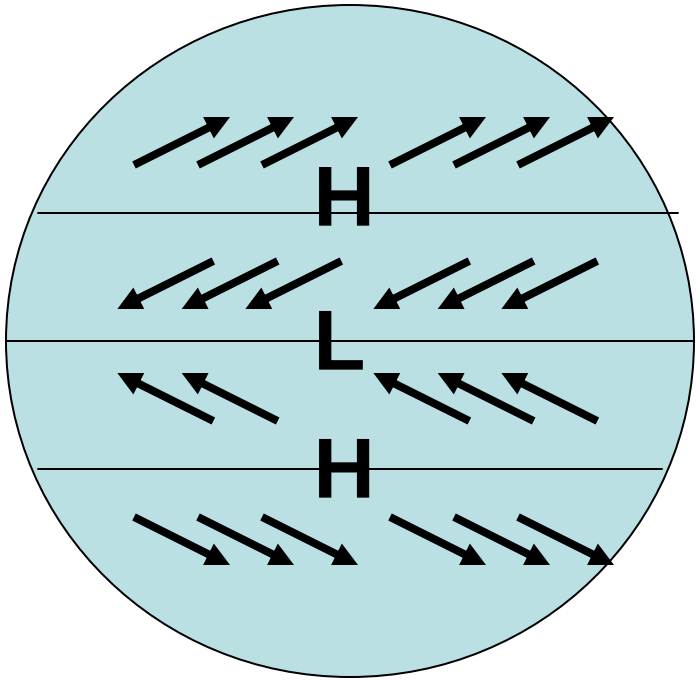
Wind from the south west (SW)

These are on the Polar sides of H's.

Wind from the north west (NW)

Summary of the Main Trade Winds

As an interim summary, here are the Easterly and Westerly Trade Winds, and now you know how they are created, and which is normally faster.



Westerly Trade Winds

Easterly Trade Winds

Westerly Trade Winds

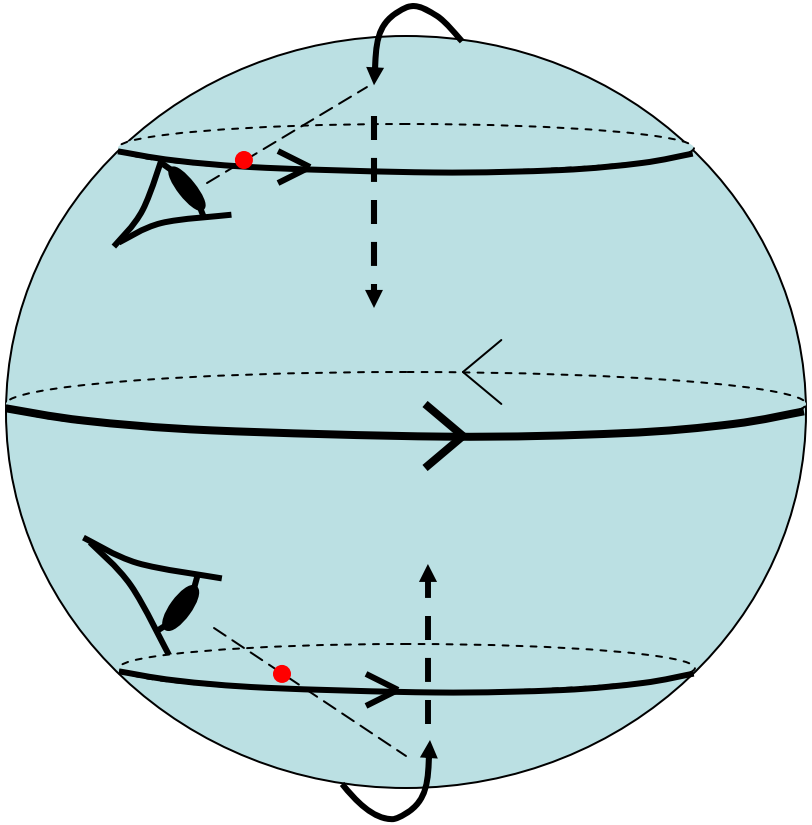
Why “Trade” Winds???

Sailing ships of centuries ago, not having engines, used to follow the best regular wind directions to sell and buy goods, to ‘trade’, as quickly as possible so that apart from the business aspect, crew did not have to spend excessive days on board when possible.

So to go west was closer to the equator; to go east they went further from the equator – the polar side of the ‘High’.

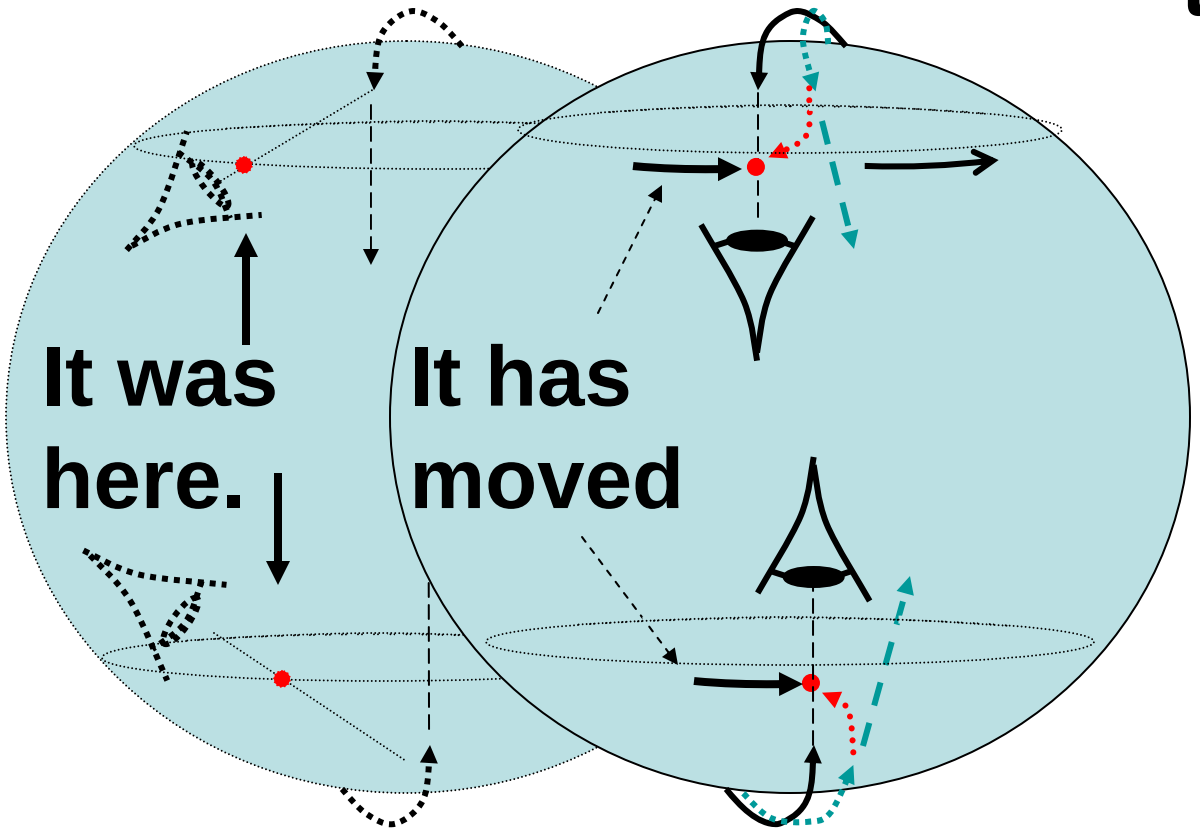
The Easterly Polar Winds

At seen from a point, •, on the earth moving west to east, a wind over the pole may be observed. It follows the curvature of the earth going straight, north or south – it appears it will cross ahead over the point's (•) path.



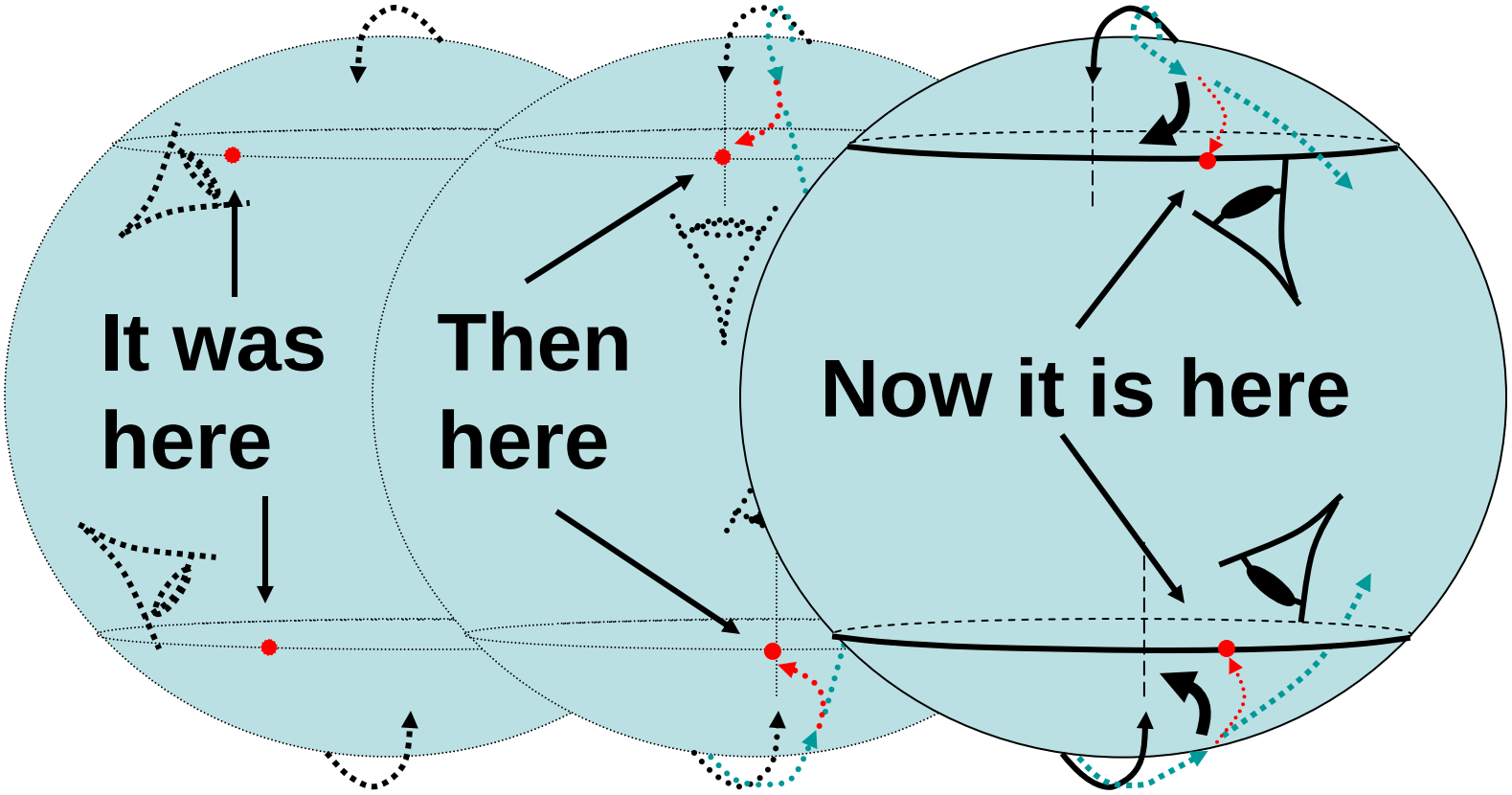
But will it?! …

Having moved towards the east, after a while the wind that appeared to be about to pass ahead over the point's path, , is now coming straight at the point, . The winds' tracks have curved towards the west .



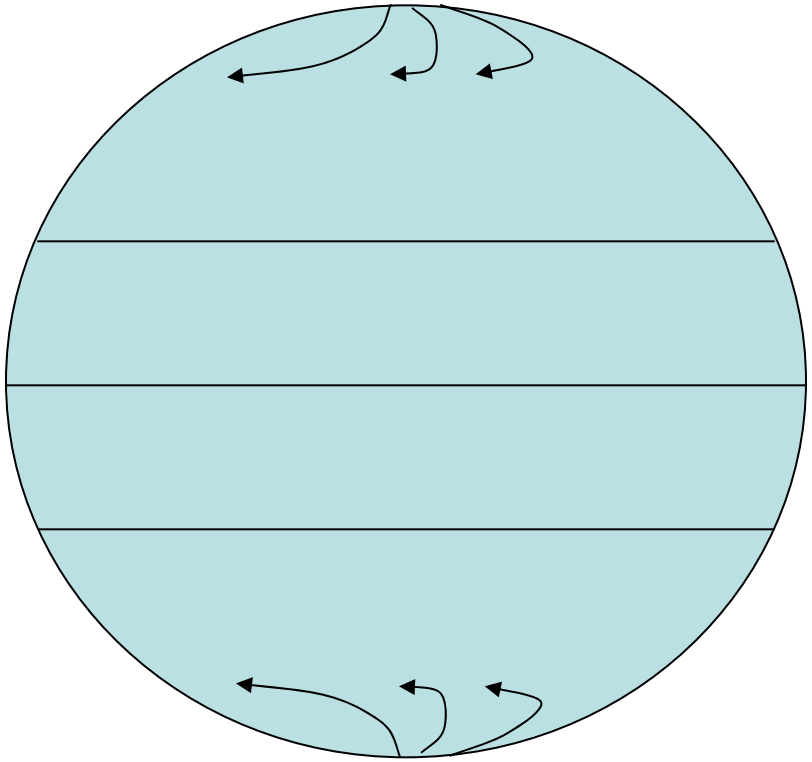
So the Polar wind is turning!

Later, the point • having moved further to the east as the earth rotates, the wind is seen to pass behind the point, ↙ ↰ , across its track.



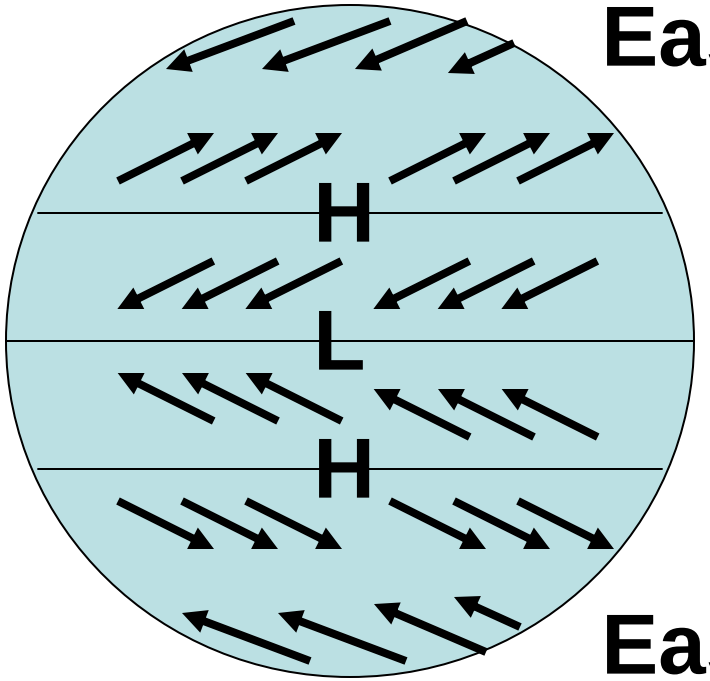
CORIOLIS

What we have been seeing is the curving of the polar wind towards the west, i.e. it comes from the north east in the north and south east in the south.



This cold wind from over a pole is therefore called the Easterly Polar Winds. They can be regarded as, but are not, Trade Winds.

So the three basic types of winds are:



Easterly Polar Winds

Westerly Trade Winds

Easterly Trade Winds

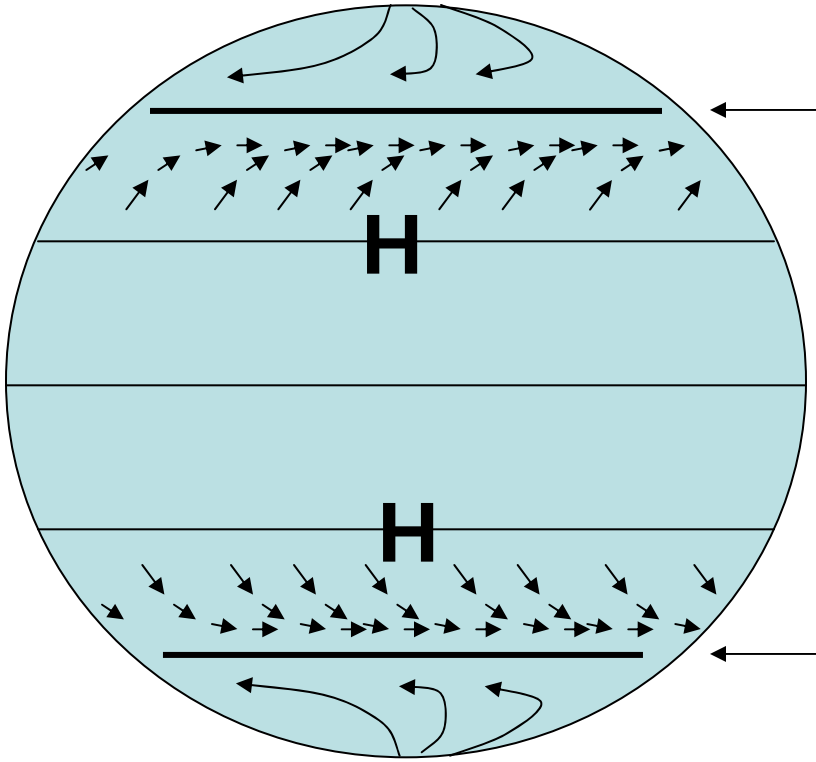
Easterly Trade Winds

Westerly Trade Winds

Easterly Polar Winds

The “Polar Front”

The Polar Fronts are the areas between strong winds blowing in opposite directions on the polar sides of the high pressure areas.



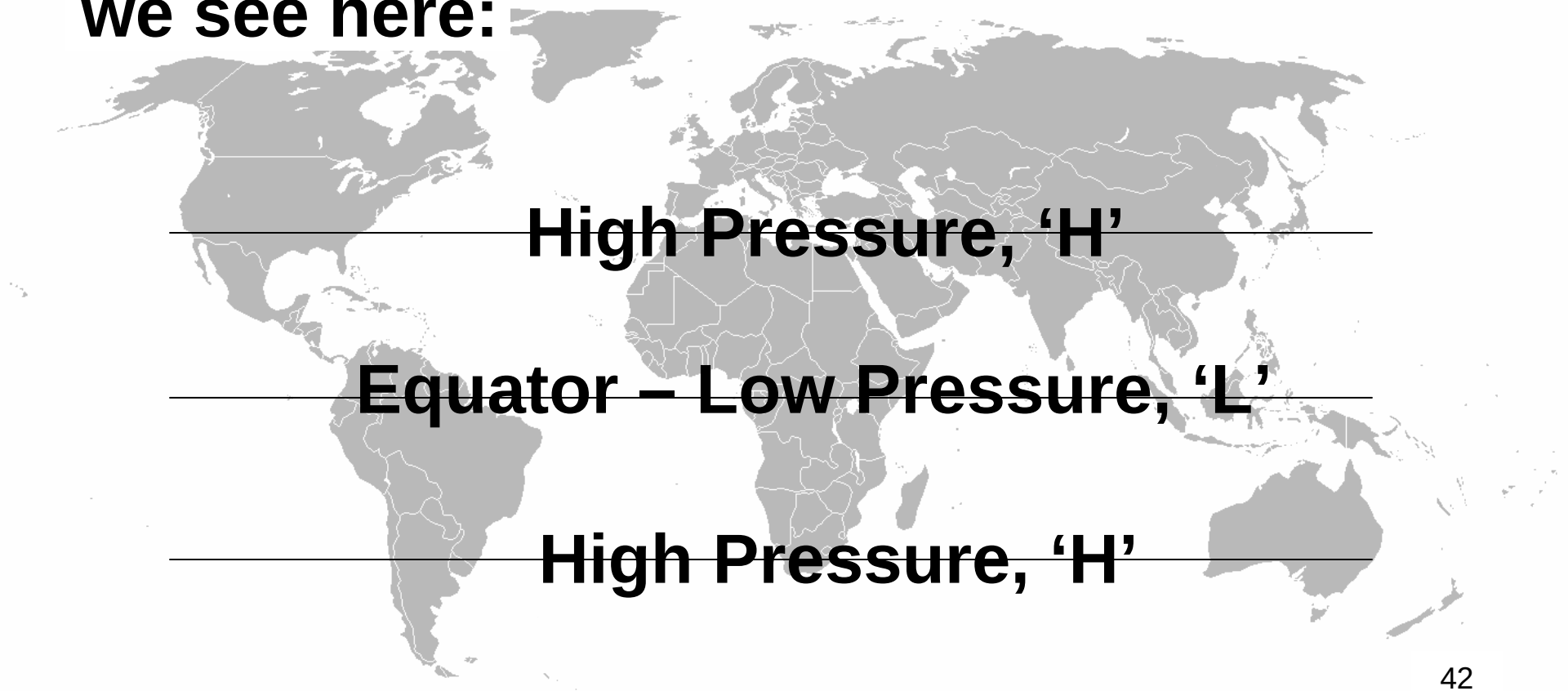
A Polar Front

Later we see “Cold Fronts” on page 107.

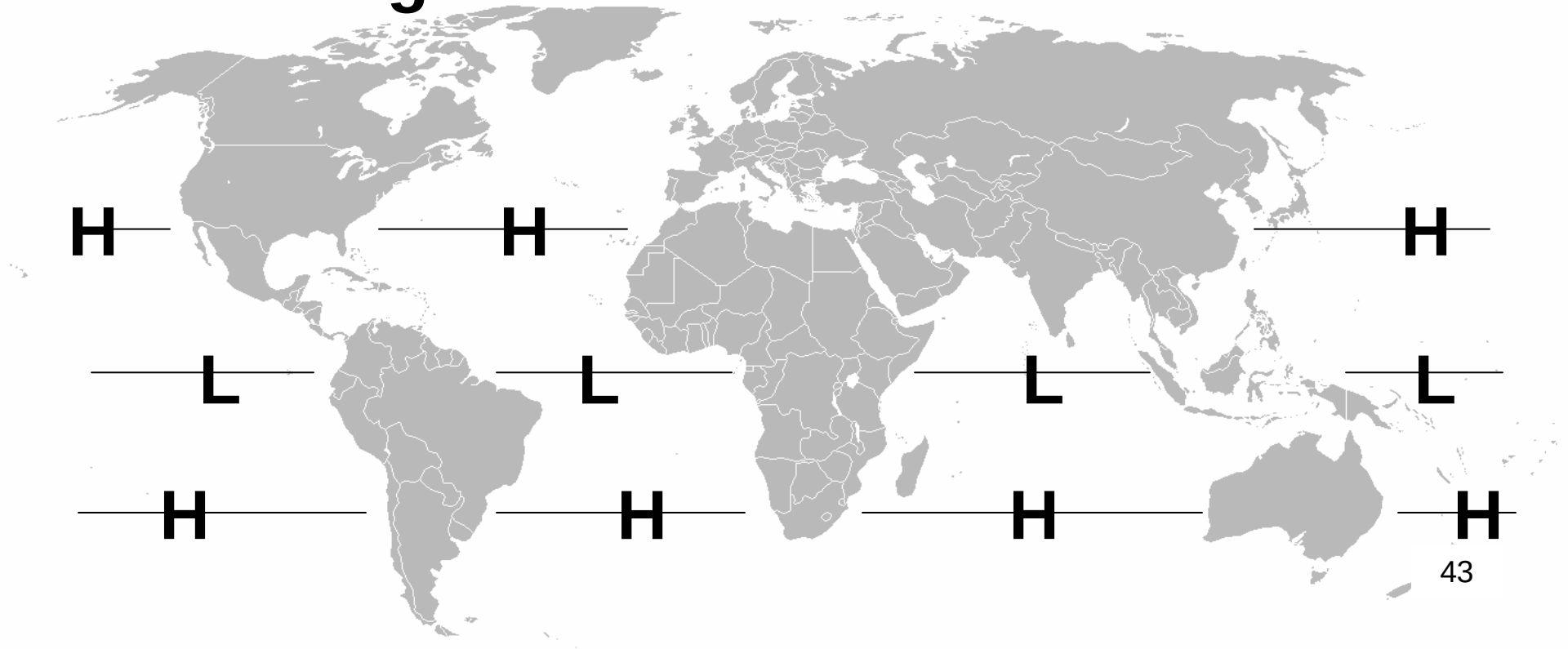
A Polar Front

Oceans' Winds

From what we have seen so far, we would believe the lines of High and Low pressures around the world would be like we see here:



Now we know land is higher than sea level, the higher the colder – and land can be hot by day and cold at night. Sea temperatures remain fairly constant day and night. So *<u>these</u>* High, 'H', and Low, 'L', pressures can be regarded more stable over the sea:

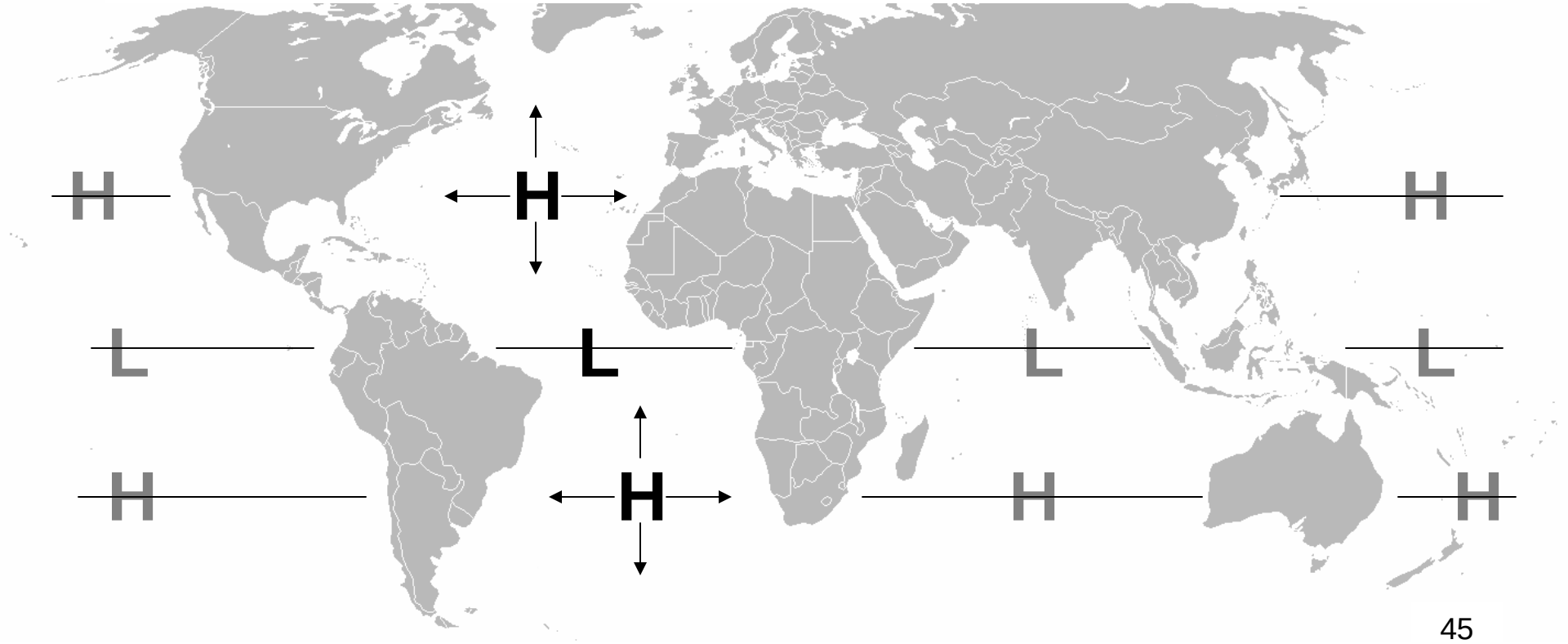


High Pressure

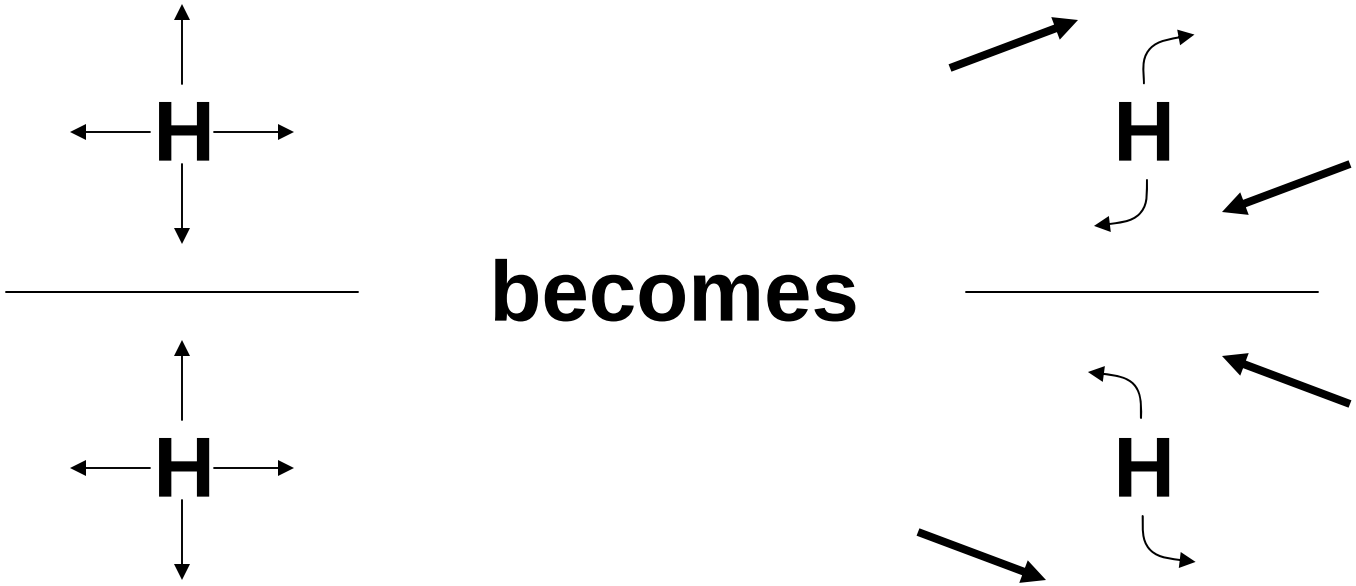
When a bicycle's tyre, car's wheel, or a balloon, each with high pressure air inside it, is punctured or bursts, the air under high pressure immediately rushes out to the surrounding lower pressure air – nature tries to establish equilibrium, 'even pressure', everywhere.

So without something to restrain it, high pressure moves towards low pressure.

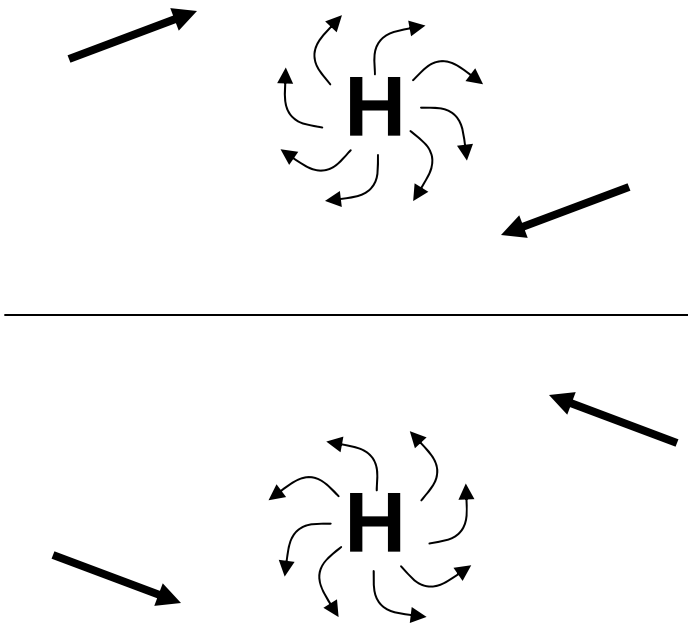
So we have ocean High pressures. The highest pressure is somewhere near the centre of its hemisphere ocean. The pressures north and south of the Highs decrease – as it does on lands' sides.



Now, knowing that at sea level in the north and south hemispheres high pressure air moves away towards lower pressure areas, and if we see the effect of trade winds, we see …



And the ‘domino’ effect causes all wind blowing away from the centre of the high(est) pressure to curve in the same direction:

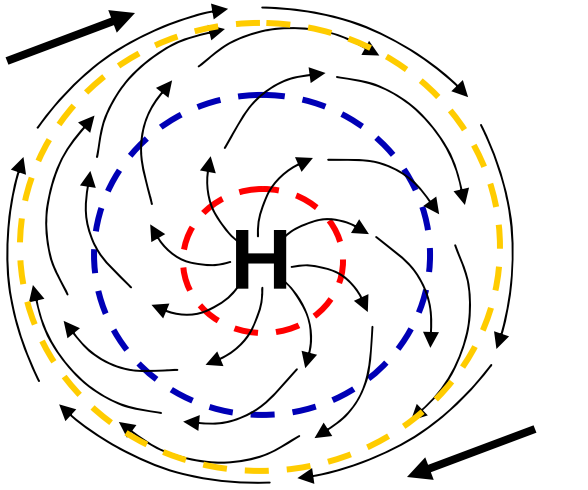


A High Pressure is called an

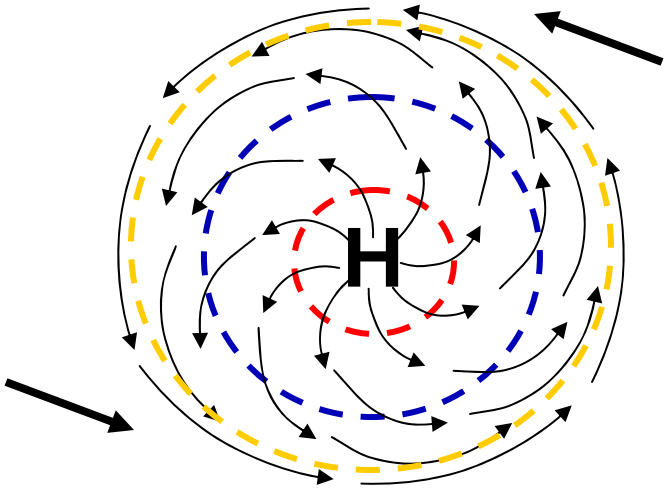
Anti-Cyclone

– irrespective of wind direction

We see the direction of the outer winds becomes closer and closer to being parallel to the circumference, an <u>ISOBAR</u>.



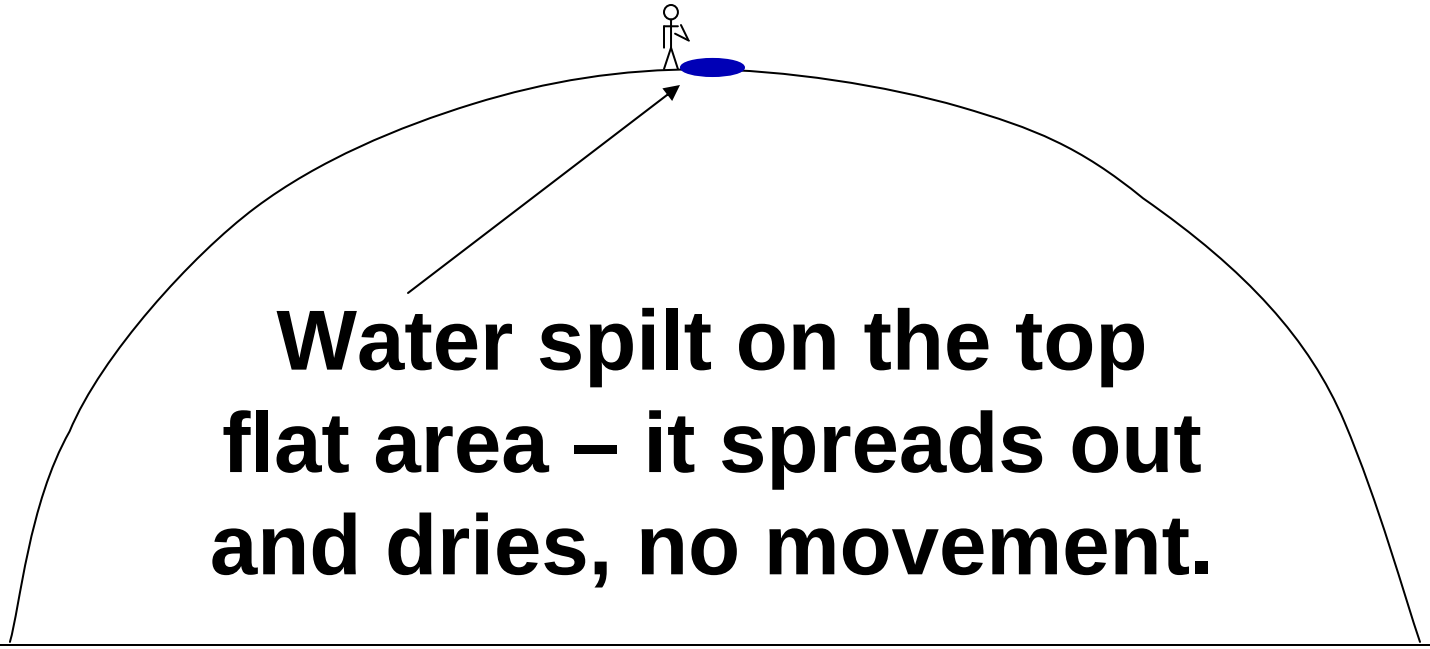
As air starts to move away the angle between the wind direction and a near circumference is big.



As it gets further out the angle decreases.

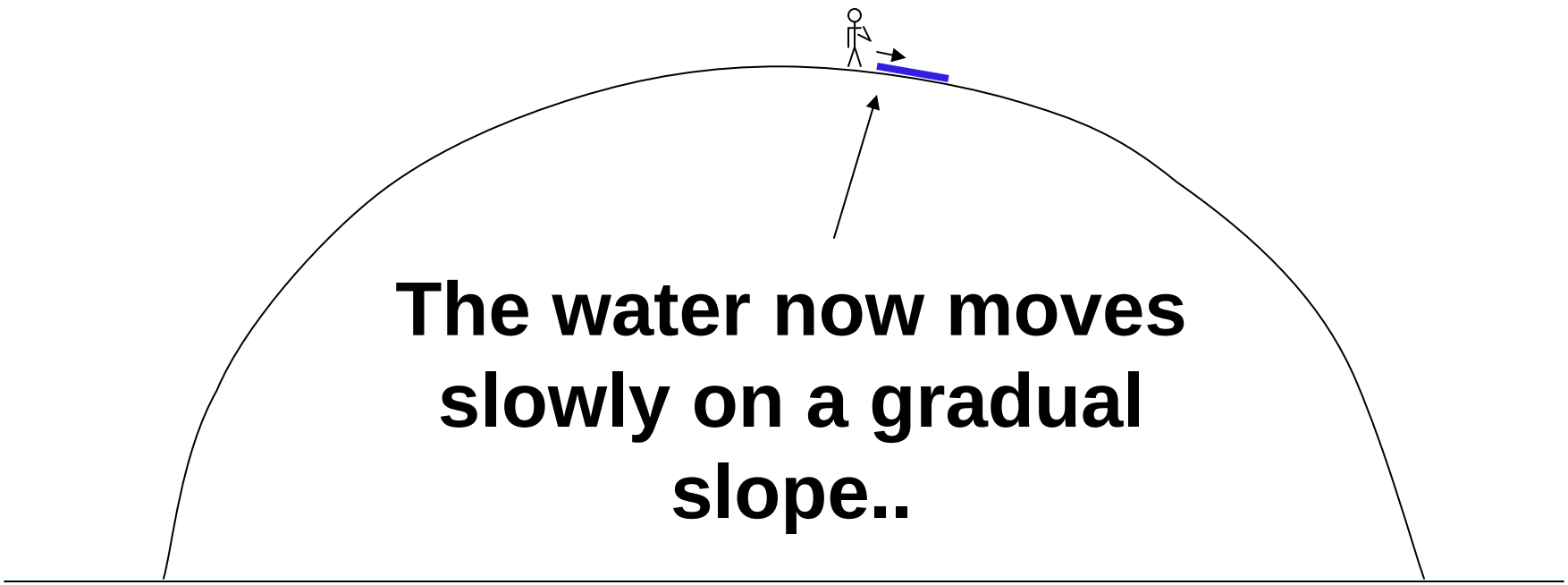
When further out it becomes parallel to a circumference.

What is an “ISOBAR”? Now imagine you are standing at the top of a very large hill shaped like the top half of a ball. You relax after climbing and have a drink of water – oops, you spill some …

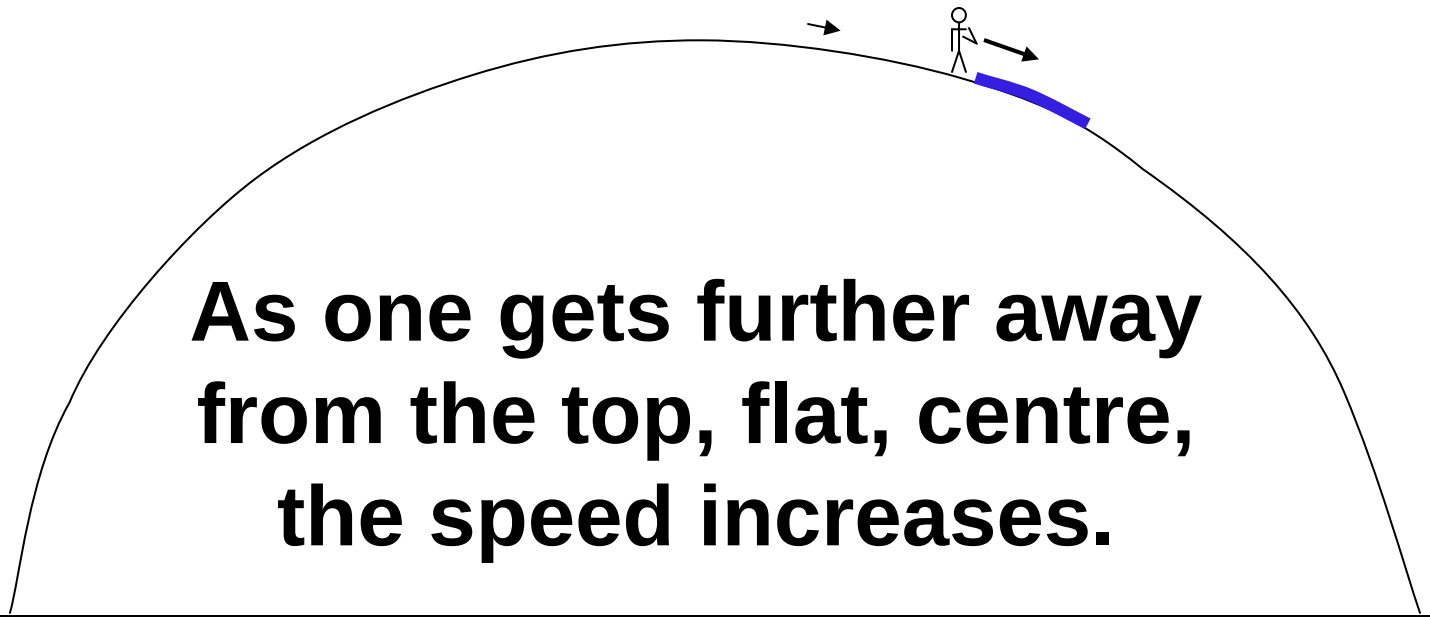


Water spilt on the top flat area – it spreads out and dries, no movement.

If you spilt some of the water when you were near but not quite at the top of the hill, where you are on a slight slope, the water would SLOWLY start to drift down.

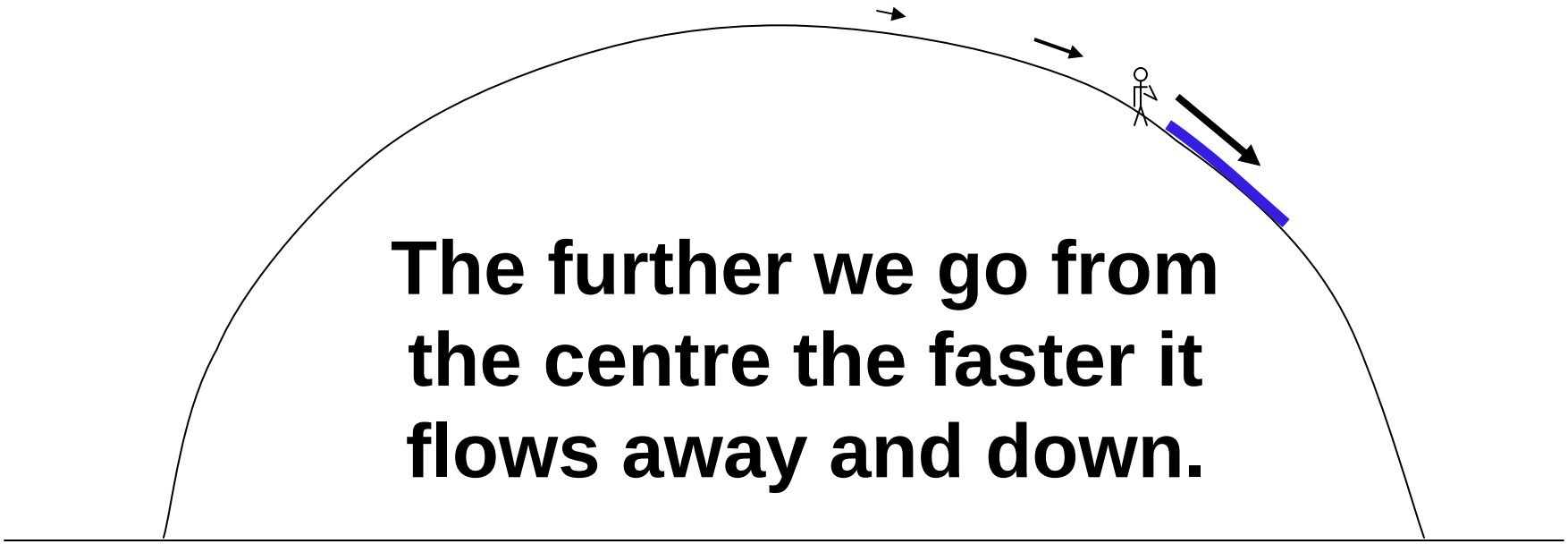


If you had been where it was a little steeper when you spilt water, the water would spill over a larger downward area, drifting down a little faster.



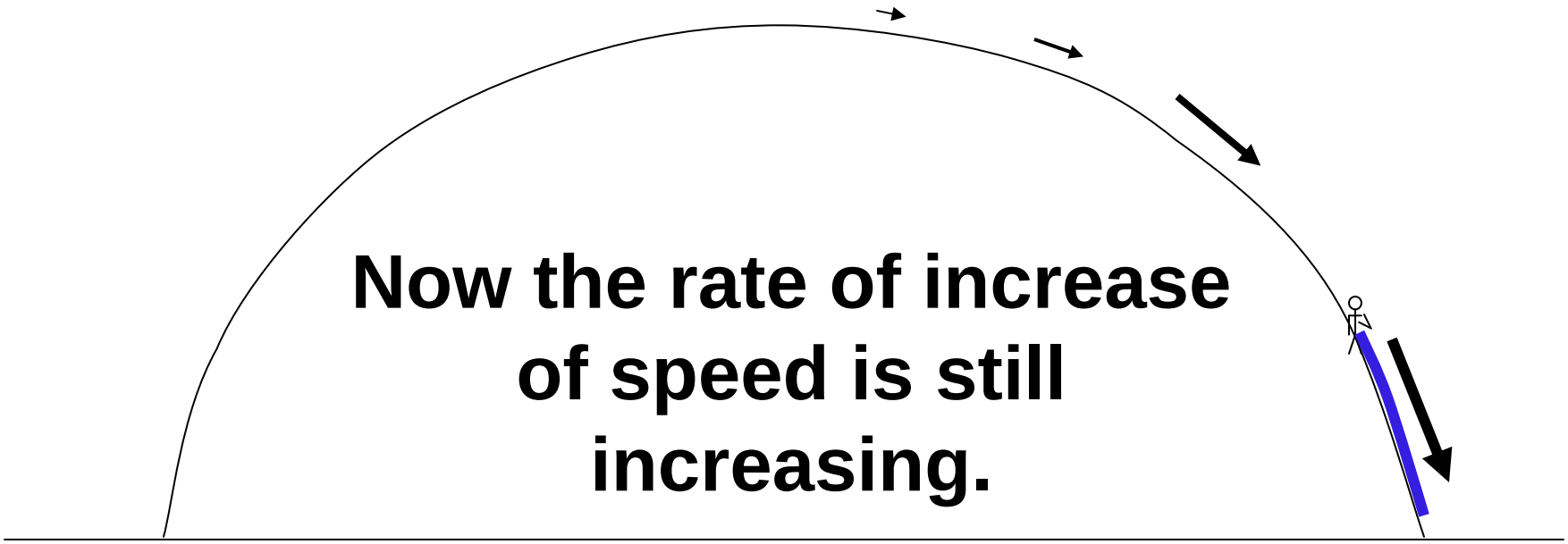
As one gets further away from the top, flat, centre, the speed increases.

If it happened where it was quite a bit steeper, the spilt water would run down even faster.



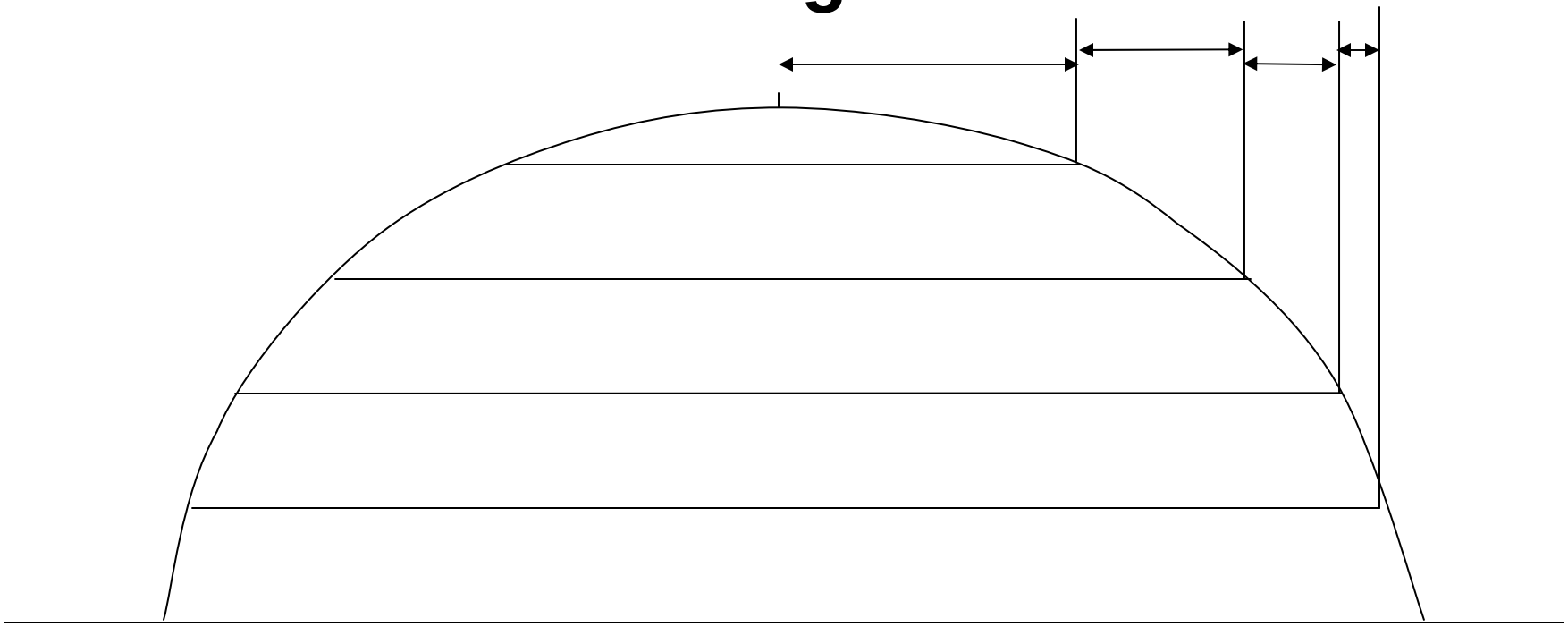
The further we go from the centre the faster it flows away and down.

Near the bottom of the hill it is very steep – the spilt water will rush downwards fastest.

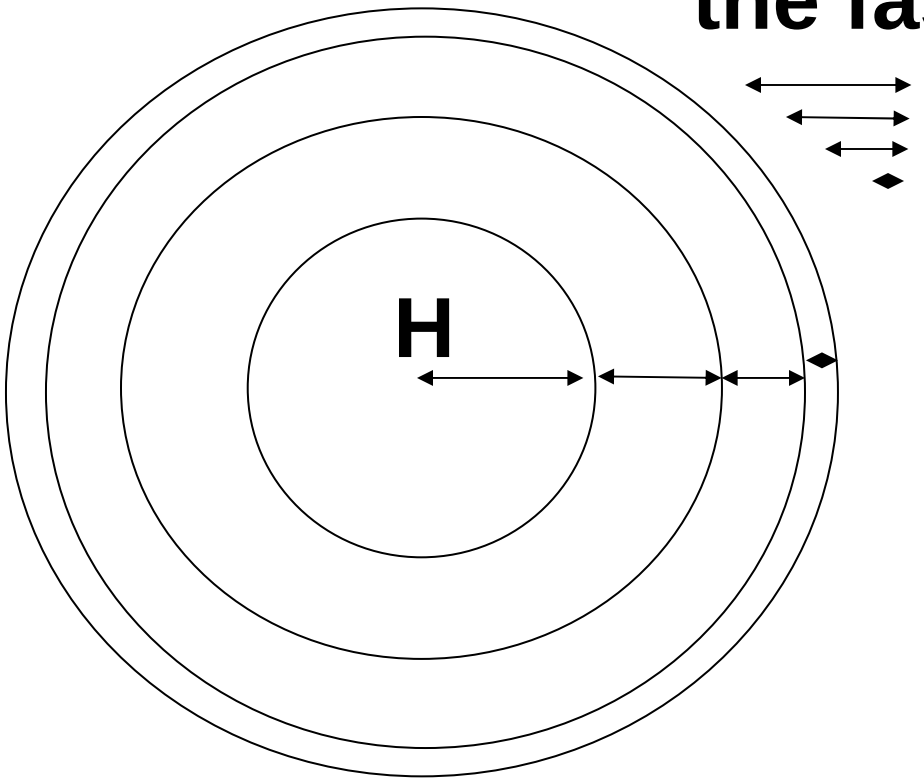


Imagine there was a ring painted around the hill at ‘χ’00 m height intervals …

Notice the further from the top centre, the shorter the (horizontal) distance between rings.

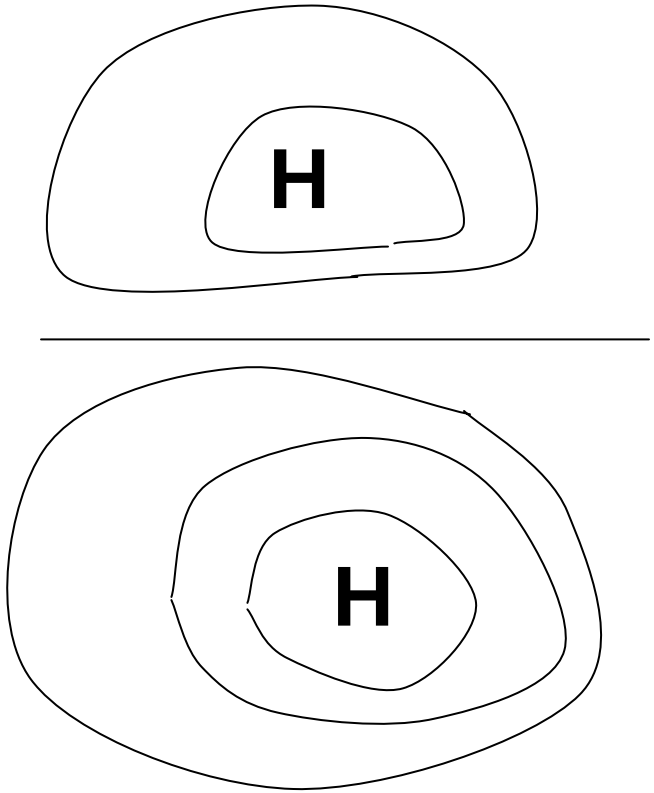


It is the same when we see the high pressures in the oceans' hemispheres. Wind at the centre of a High is zero! As we get further away the wind starts to develop; the closer the "rings" are, the steeper the slope, the faster the wind flows.



For meteorology, the "rings" are ISOBARS. The closer they are, the stronger the wind speed.

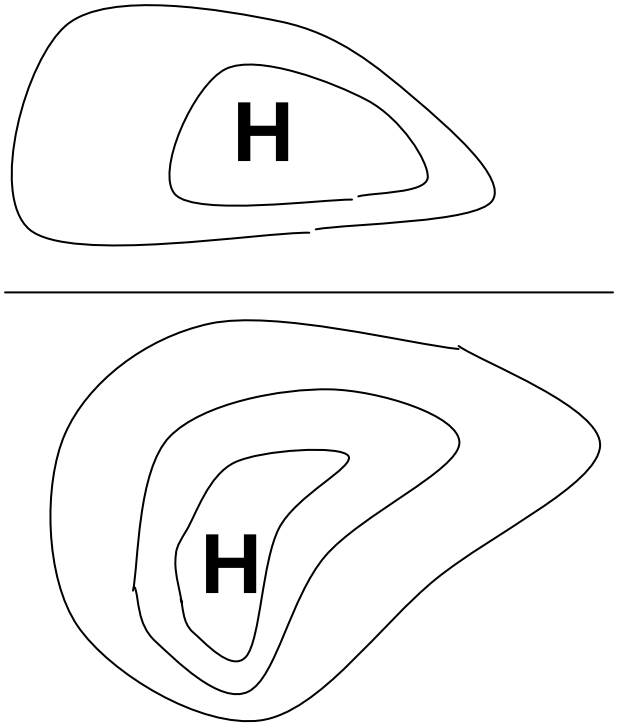
Isobars are not perfect rings or circles – they mark all points of the same pressure. For most weather charts they are showing the present shape of the pressure area.



Northern Hemisphere

Southern Hemisphere

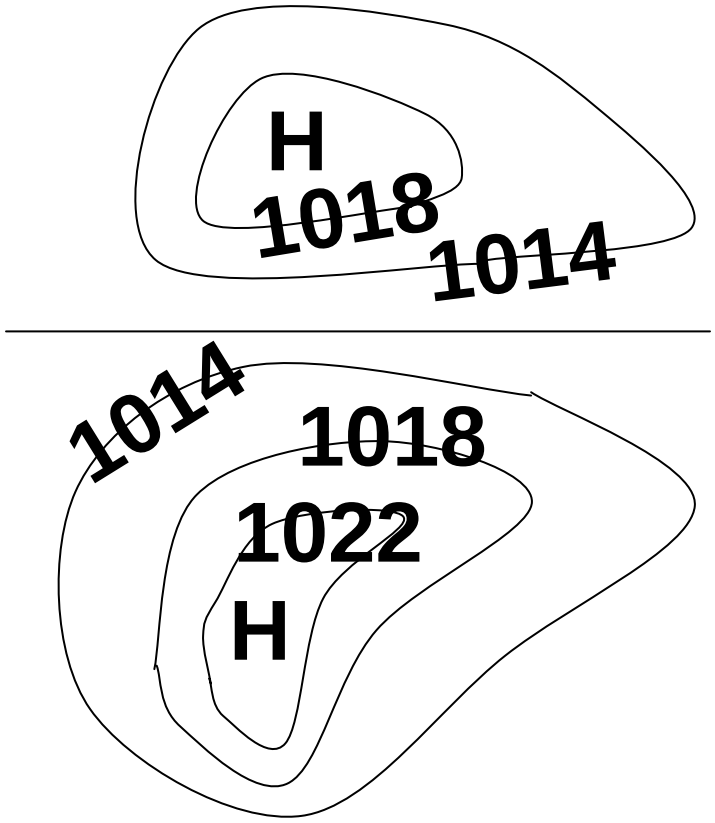
Isobars show where the pressures are different, usually every 4 mbs, millibars, and the shape and pressure are constantly changing. Here are two examples of an ocean High:



Northern Hemisphere

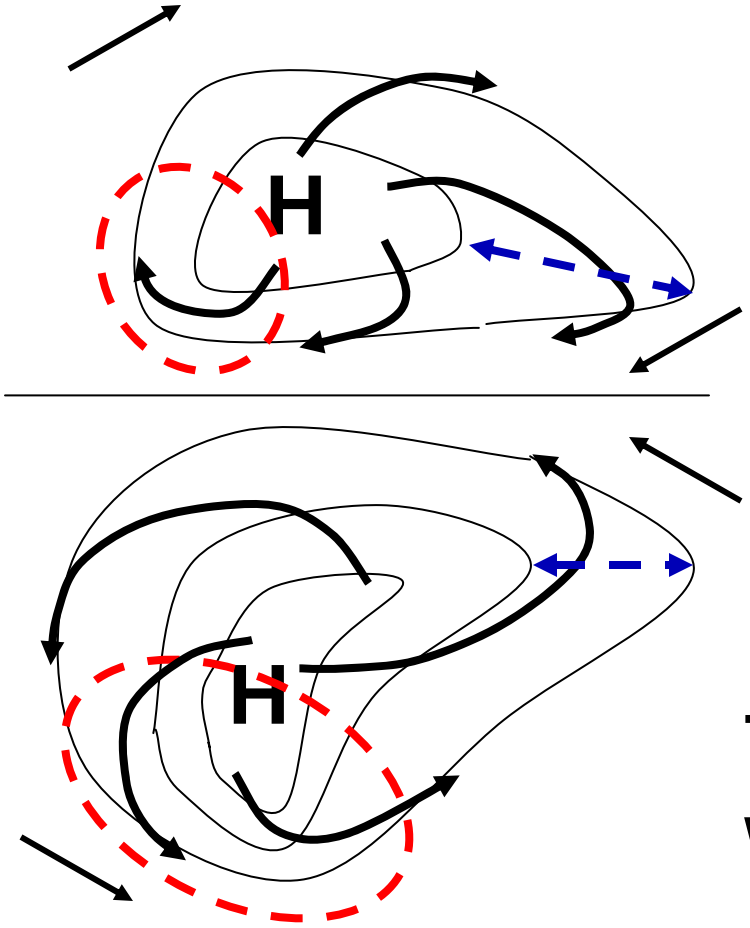
Southern Hemisphere

Here are three isobars for a higher High pressure (1022 mbs) in the southern hemisphere compared to a lower High (1018) northern hemisphere pressure.



A High pressure exists when the pressure is above 1013 mbs. Isobars show multiples of 4 mbs. So Highs' isobars start with the pressure as 1014 mbs.

Now if we know the effect of the Trade Winds, we can estimate where the winds are going and where strong winds will be. We see strong wind here in ◯ , where isobars are close to each other. Mild where they are far apart ⟵ - - - - ⟶ .



Easterly and westerly trade winds cause the wind turning directions.

Barometer Pressure Changes

By regularly monitoring the air pressure as seen on a barometer, the rate of change gives us an idea how much the wind speed will change. If we check every three hours, and enter in the vessel's log book for later confirmation, we can find the approximate wind speed change to follow, usually about 4 hours after the pressure changed.

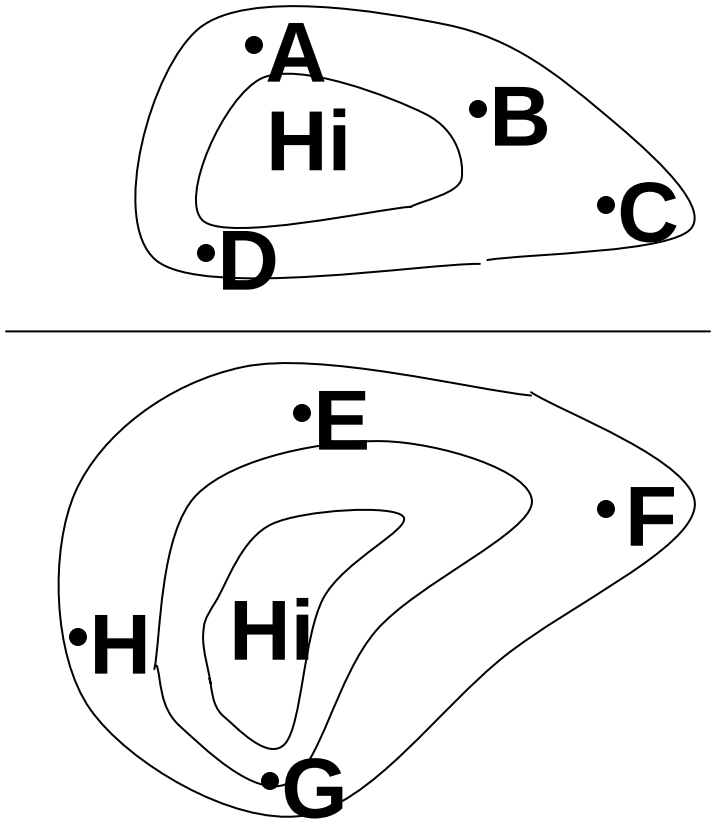
See the average rates of change: …

These rates of wind speed change, due to pressure increase or decrease, are averages

mb change up or down per 3 hours	Wind speeds up in Low Latitudes 0° to +/- 35° N/S	Wind speeds up in Latitudes +/- 35° plus, N/S
0	0 knots	0 knots
1	5 to 10 knots	0 to 5 knots
2	10 to 15 knots	5 to 10 knots
3	15 to 25 knots	10 to 20 knots
4	20 to 30 knots	15 to 25 knots
5	25 to 40 knots	20 to 30 knots

When seeing a weather map, a <u>Synoptic Chart</u>,

we can <u>estimate</u> wind speed and direction – named where it comes from:



A – 20 to 30 kns, SW

B – 10 to 20 kns, WNW

C – 5 to 10 kns, NNE

D – 30 to 40 kns, E

E – 15 to 25 kns, E

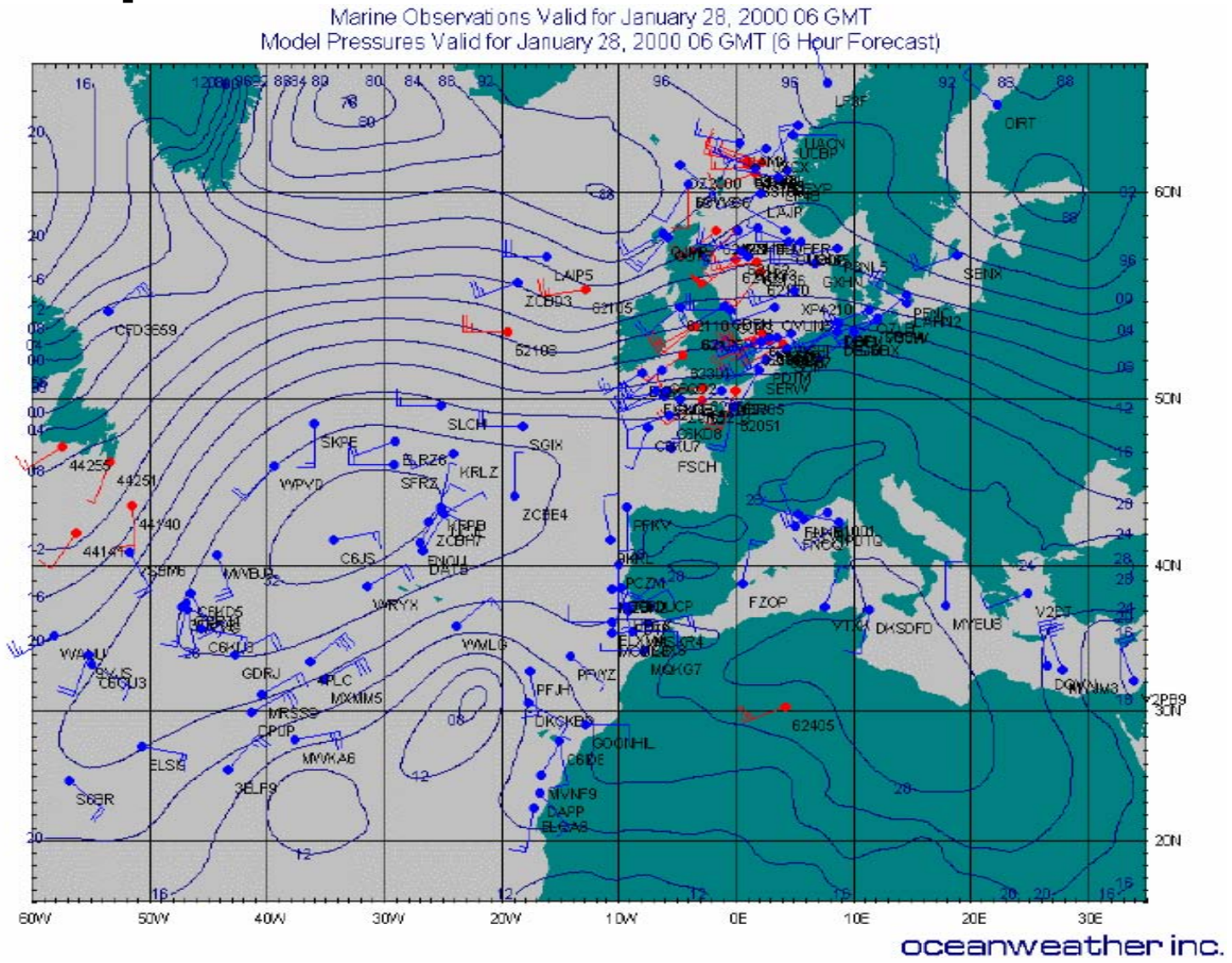
F – 10 to 20 kns, SW

G – 40 to 50 kns, NW

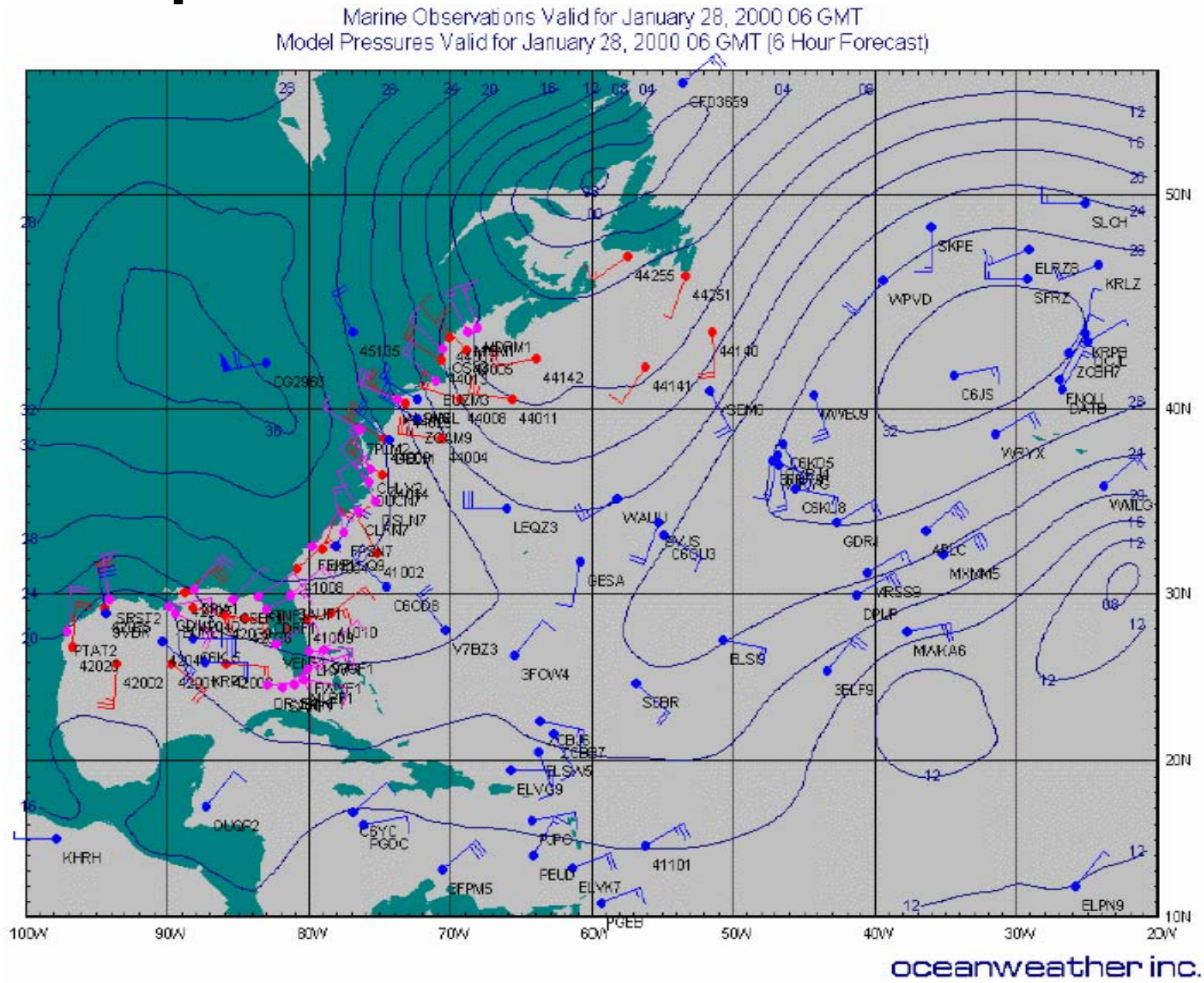
H – 15 to 25 kns, NNE

Examples from www.oceanweather.com

Example 1. NE Atlantic Ocean

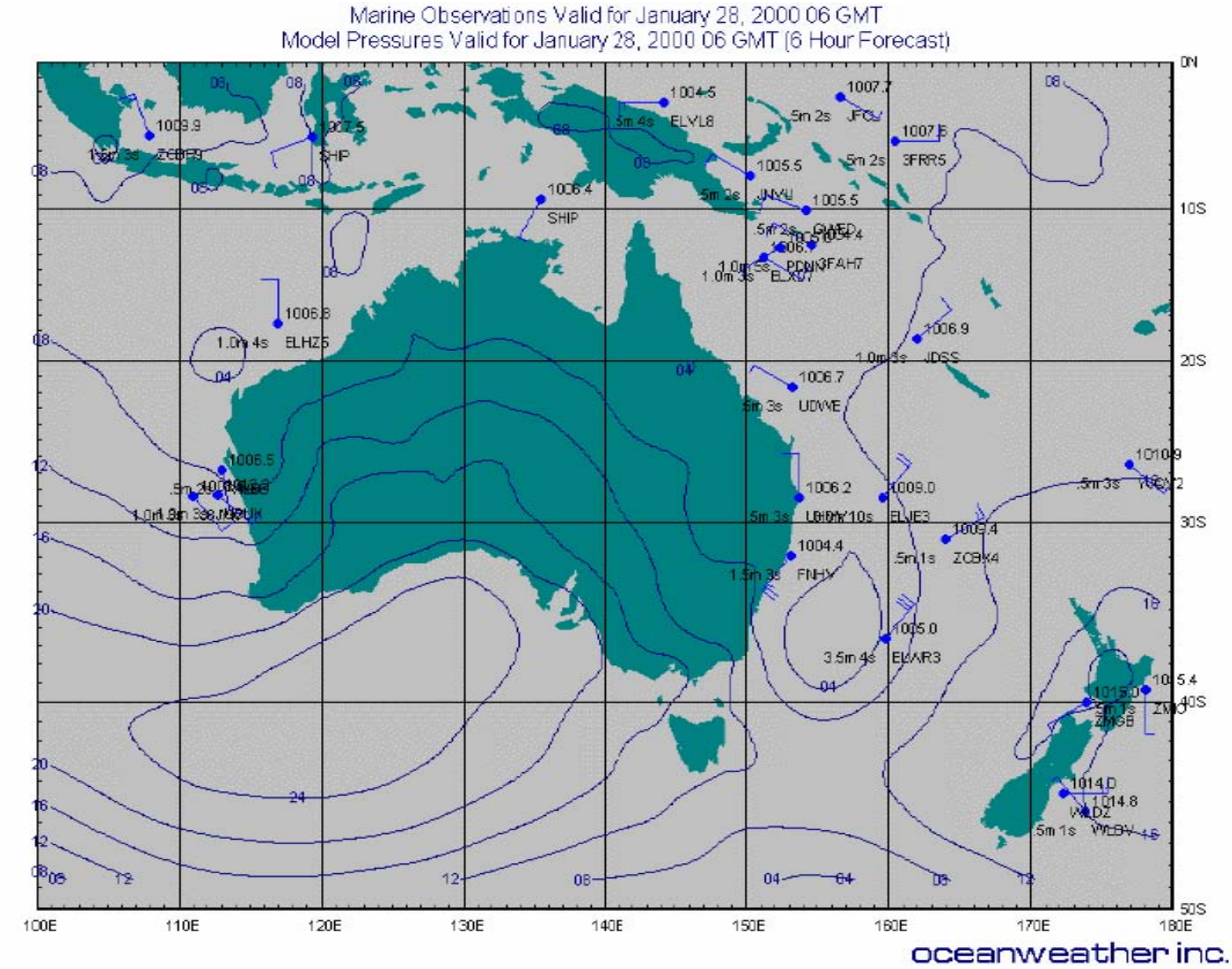


Example 2. NW Atlantic Ocean

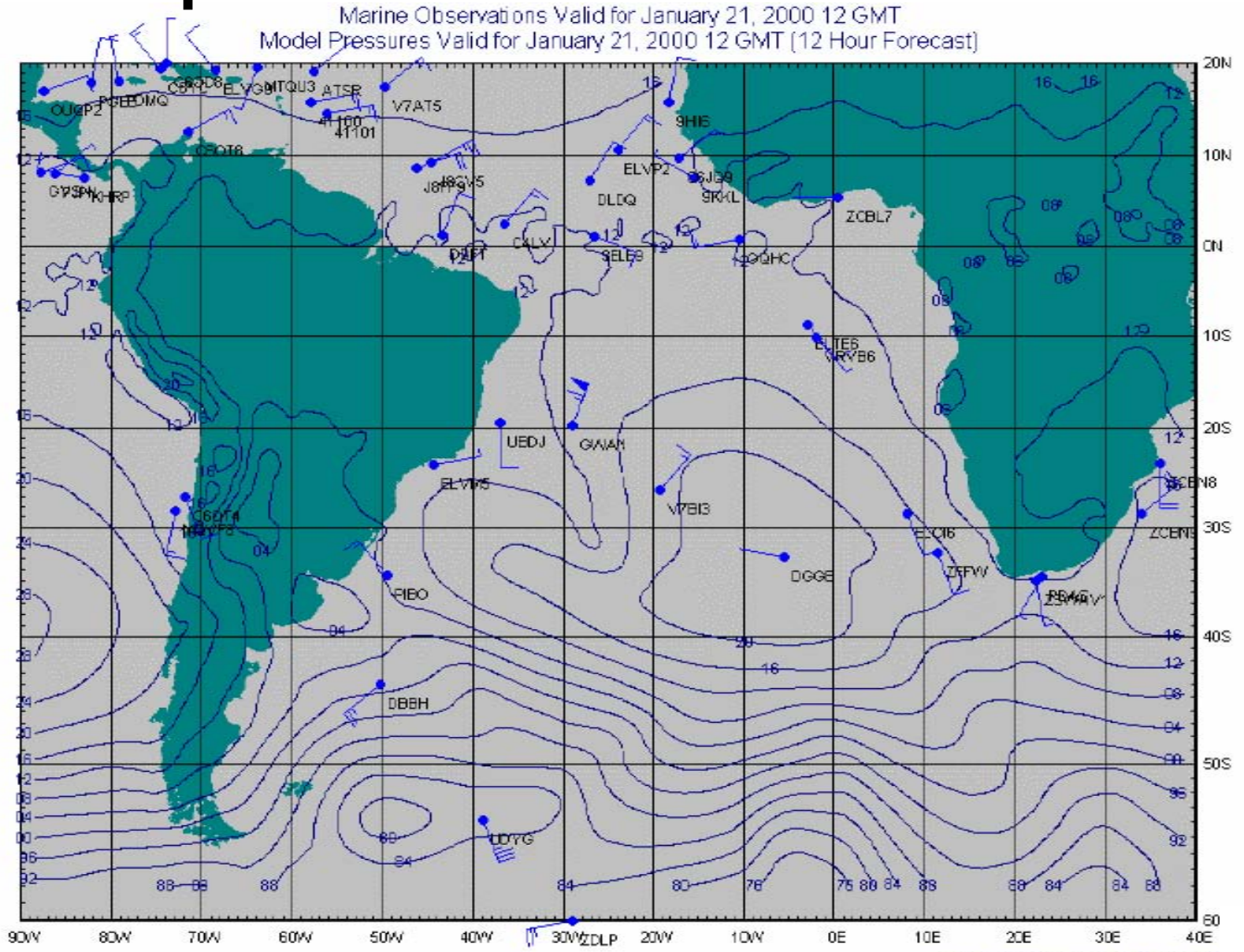


oceanweather inc.

Example 3. Australian Region

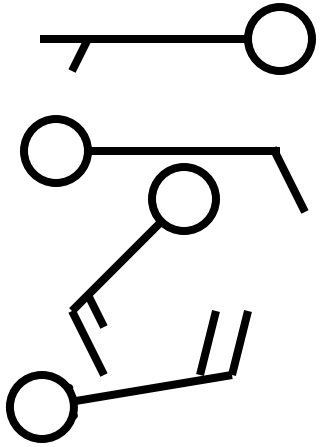


Example 4. South Atlantic Ocean



oceanweather inc.

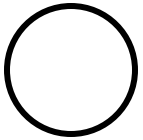
We often see the producers of the synoptic charts have recorded wind direction and speed for us – they show arrows indicating both. ⟶ are changed to ⟵○. Wind is:

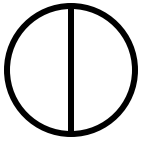


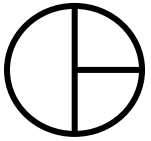
the west wind, ‘W, 5 kns’ (⟵), the wind from east, ‘E, 10 kns’, south west, ‘SW, 15 kns’, east north east, ‘ENE, 20 kns’,

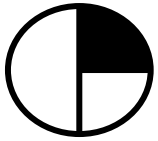
etc. Each ‘feather’ of an arrow is for 10 kns; half length is 5 kns. This would be 45 kns from NW (north west):

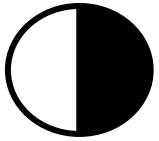
The ring at the leading end of a wind arrow shows how many eights of cloud exist at the time on the synoptic chart:

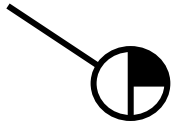
0/8th 

1/8th 

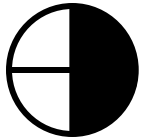
2/8th 

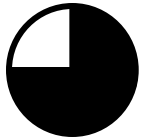
3/8th 

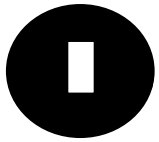
4/8th 

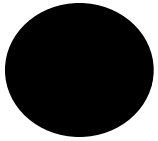


A number next to the ring shows air temperature in degrees Celsius

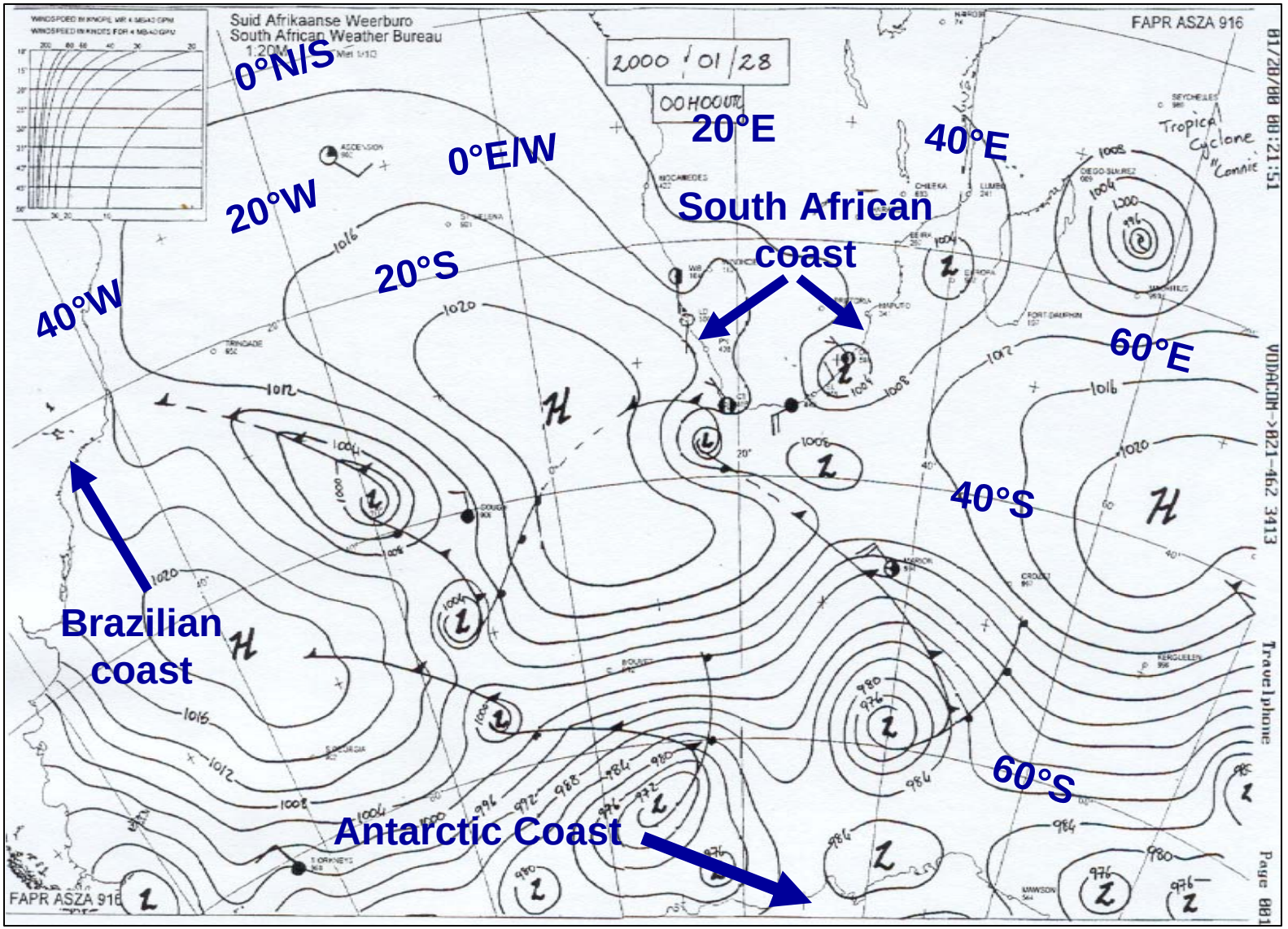
5/8th 

6/8th 

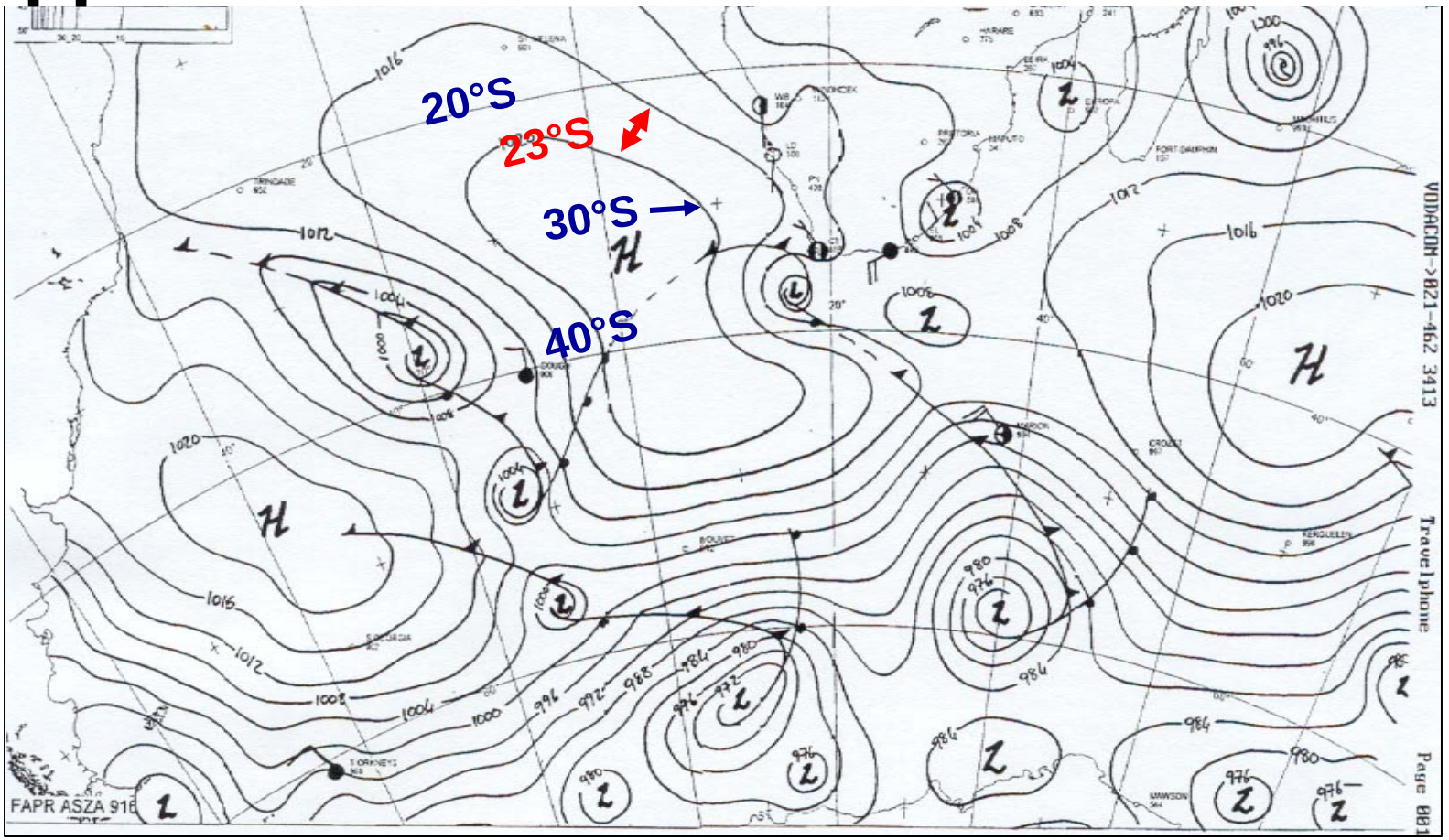
7/8th 

8/8th 

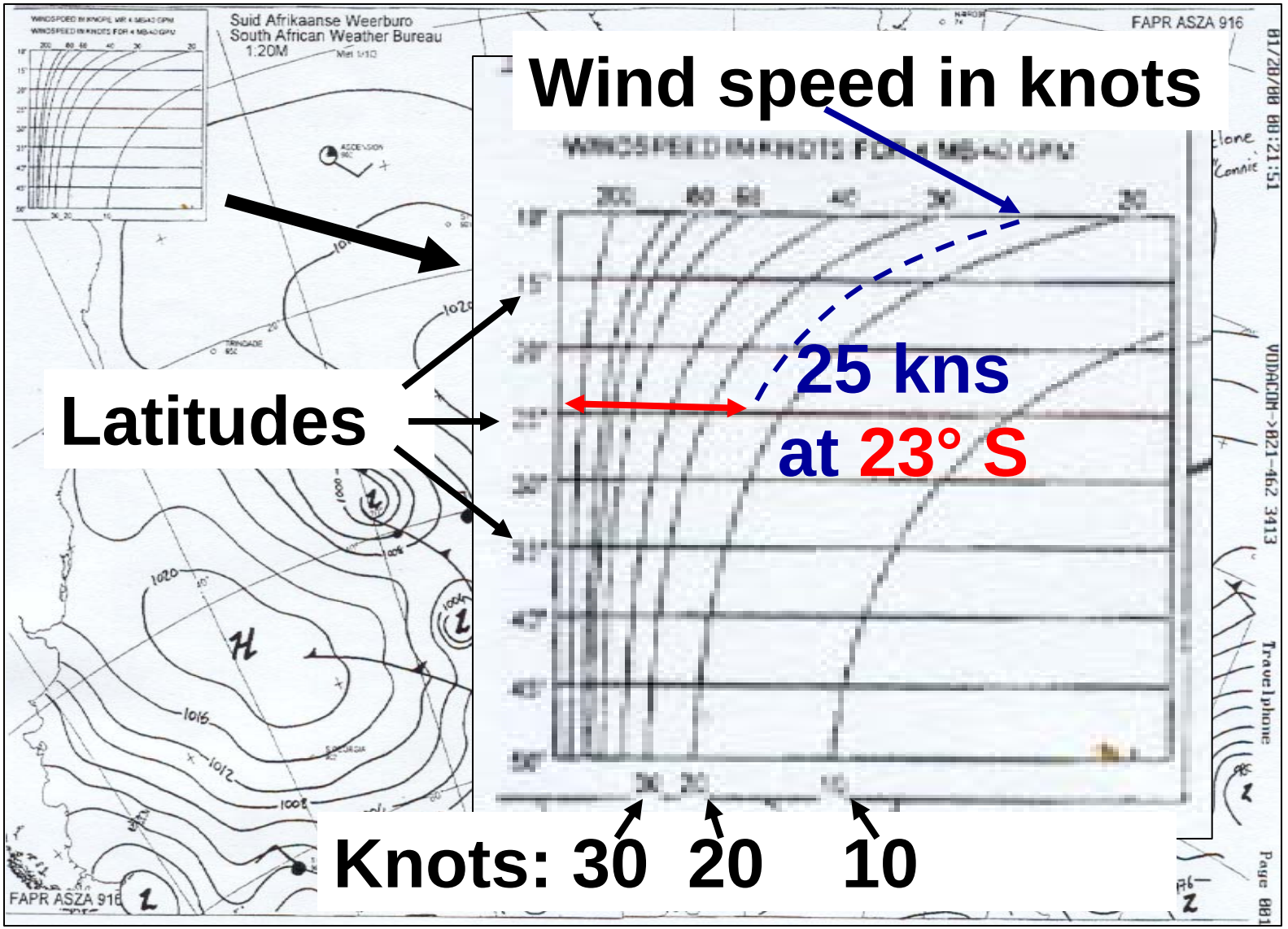
Example 5. South Africa's Weather Bureau chart shows a Cyclone in the Indian Ocean



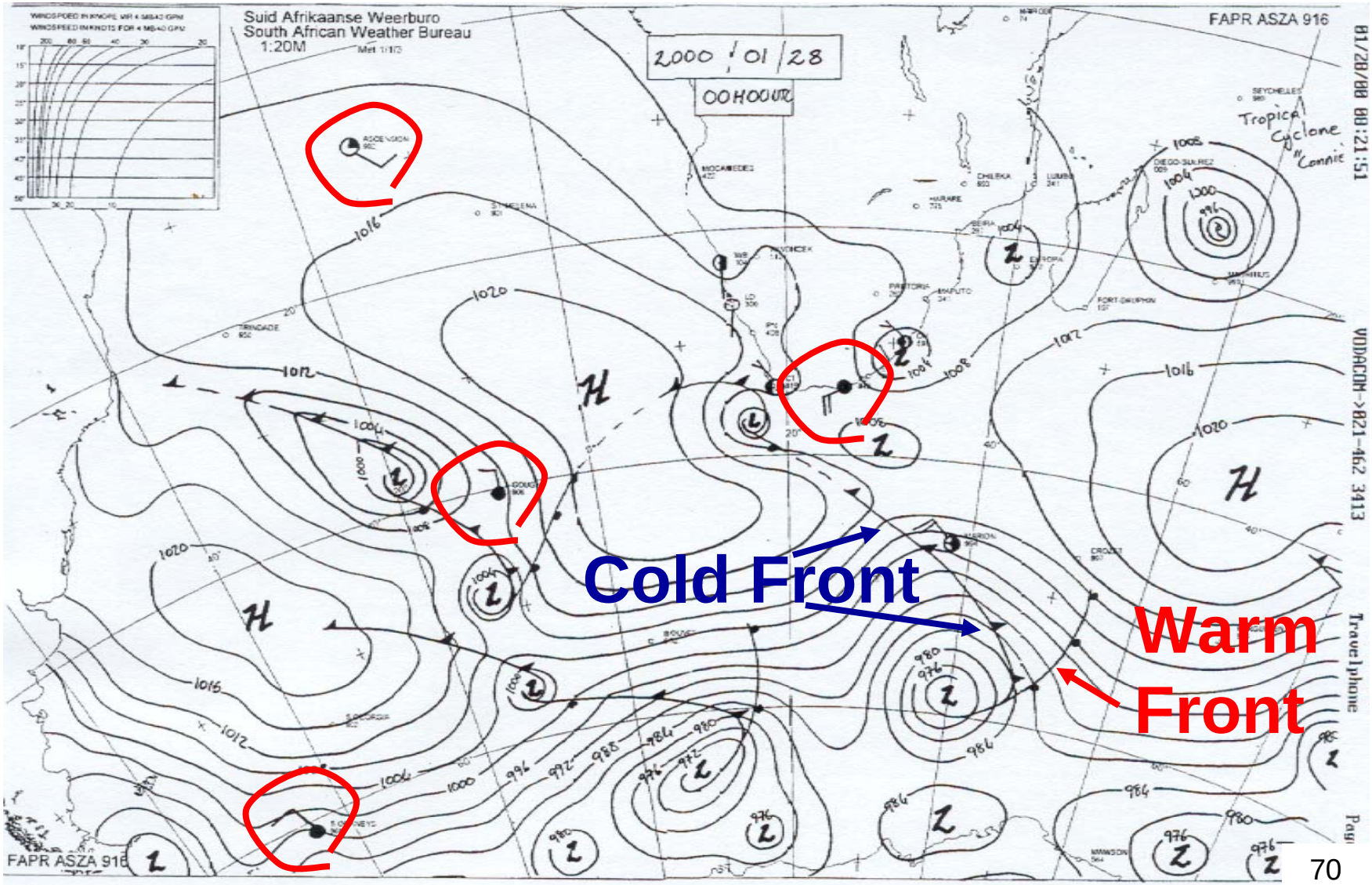
To get an idea of wind speed at any place, measure the shortest distance between parallel isobars. What is the approximate latitude where it is?



The wind speed between isobars at a latitude is seen from this graph:



Wind speed is also shown by wing arrows



Wind speed and sea state may be indicated by the

THE BEAUFORT SCALE

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State

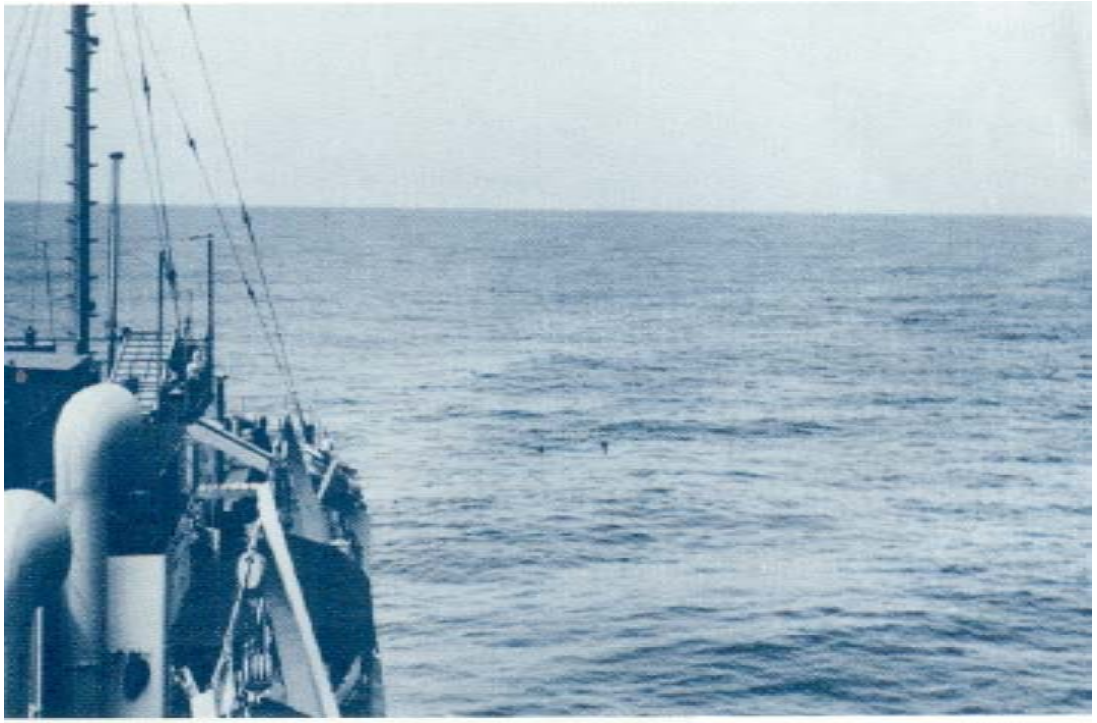
The lighter the wind, the lower the Beaufort number, the flatter the sea, – the smaller the waves or ripples.

Force 0

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
0	0 - 1	Calm	Flat, smooth, mirror-like.

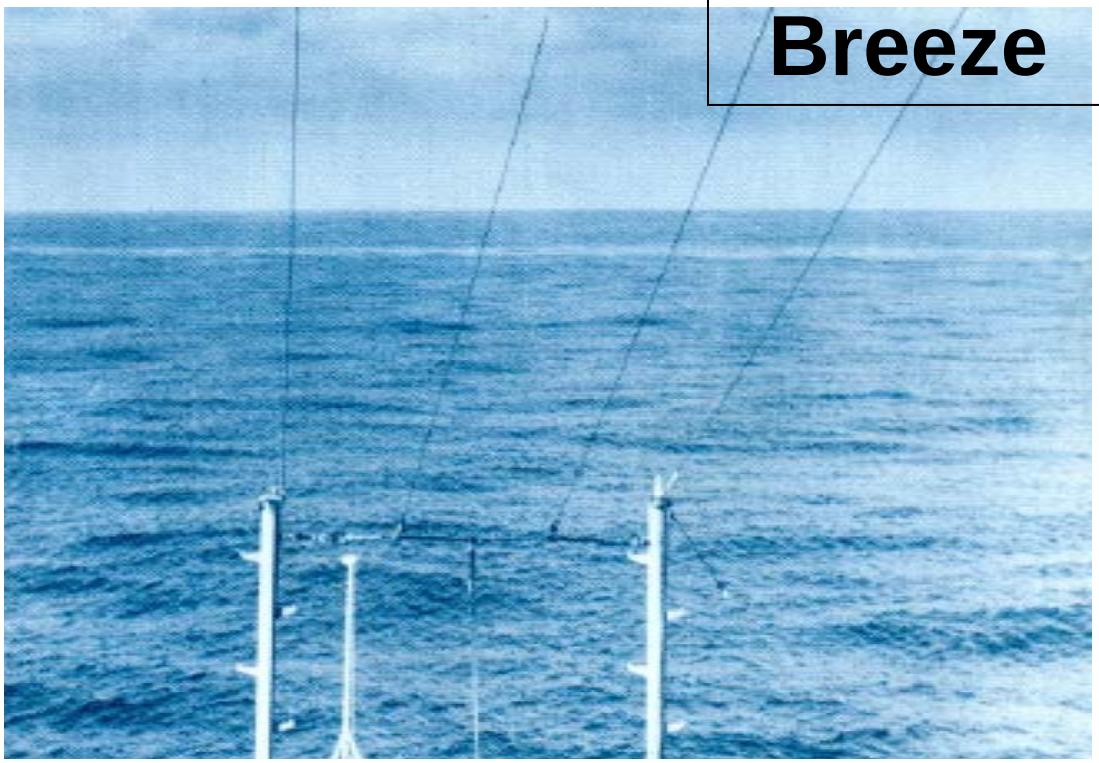
Force 1

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
1	1 - 3	Light airs	Very small ripples, 10 cms/ 3 inches



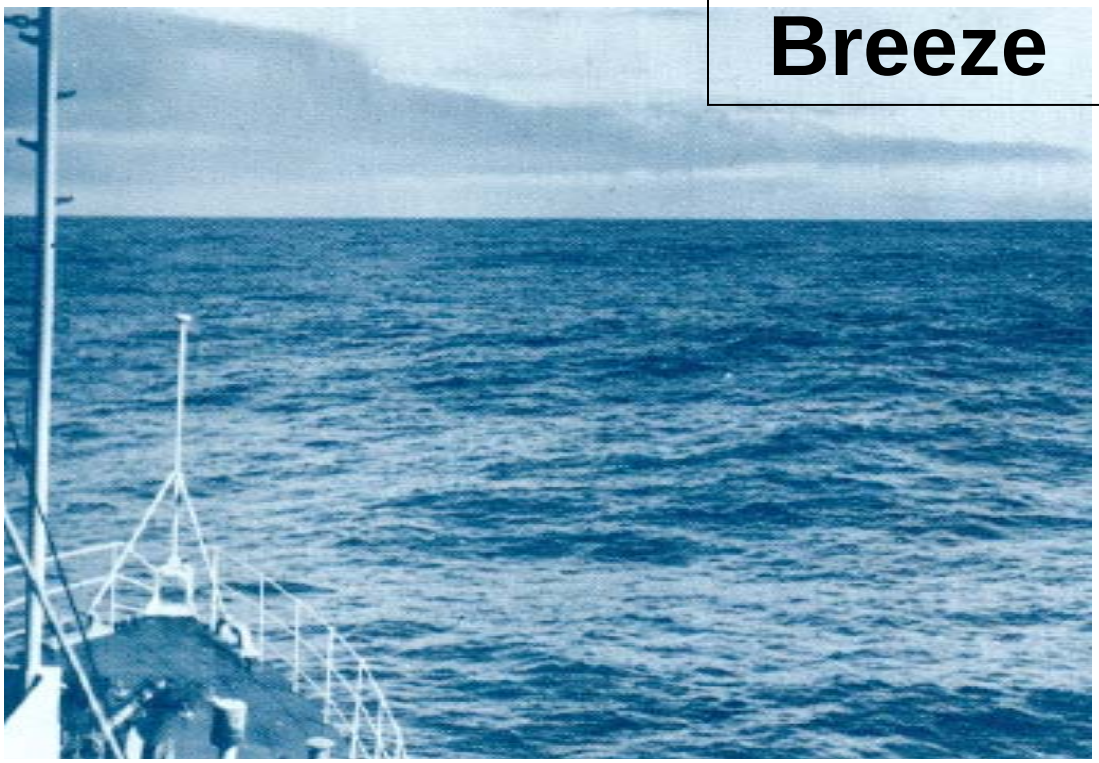
Force 2

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
2	4 - 6	Light Breeze	Small wavelets, glassy crests, 20 cms/ 6 inches



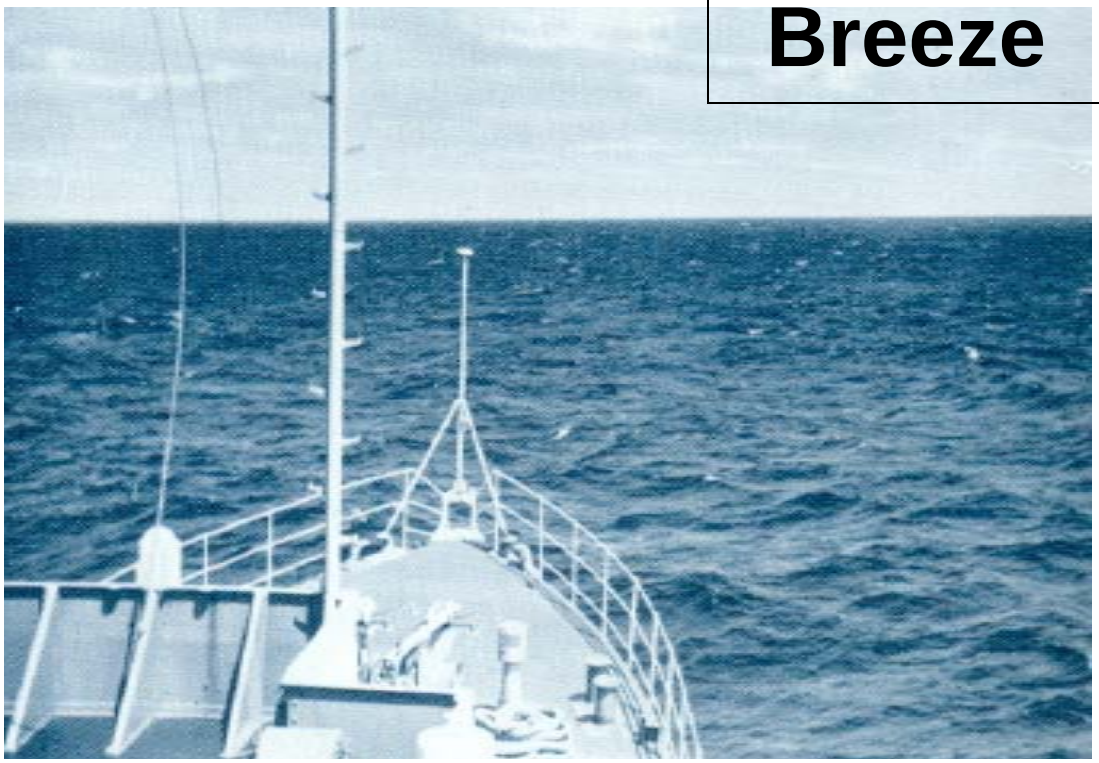
Force 3

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
3	7 - 10	Gentle Breeze	Large wavelets, no white crests, 0,5 m/2 feet



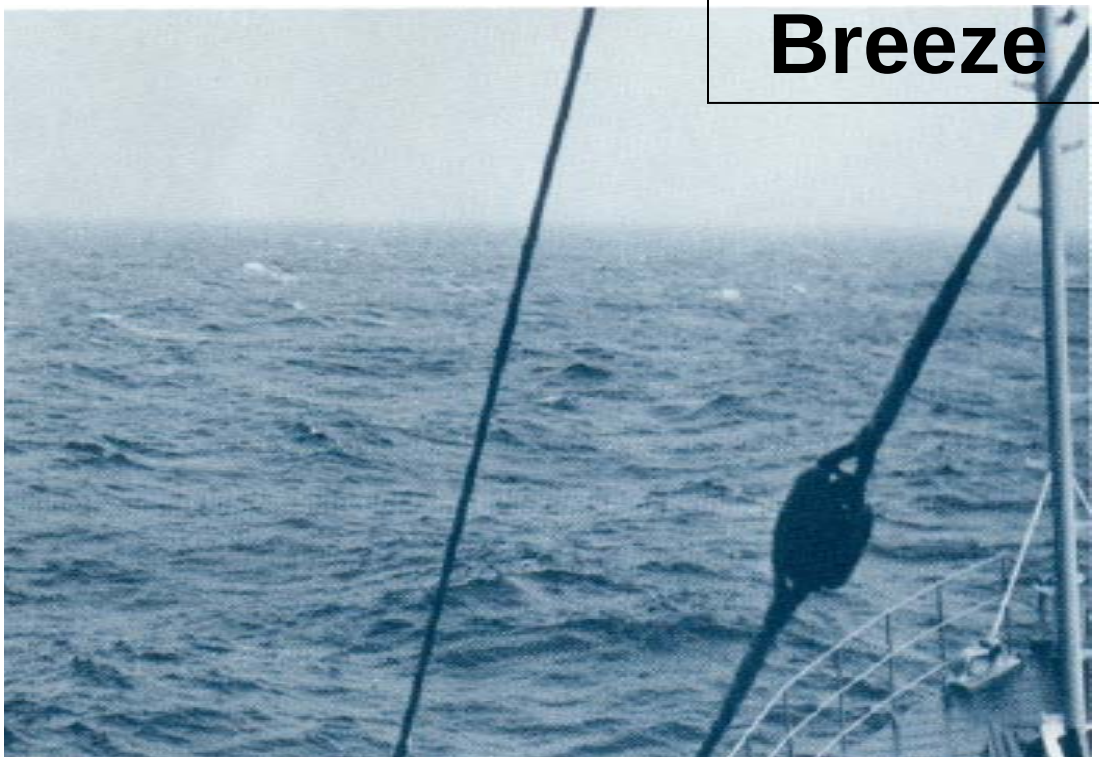
Force 4

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
4	11 - 16	Moderate Breeze	Small waves, becoming longer, white caps. 1,5 m/4 feet



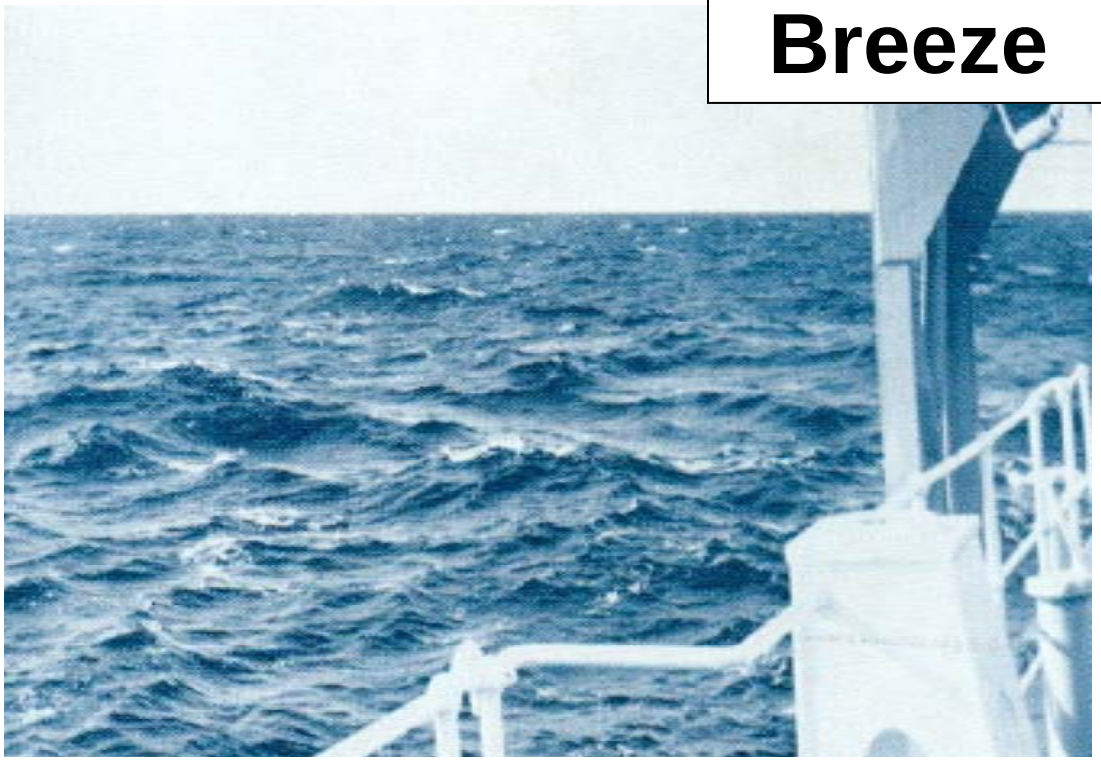
Force 5

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
5	17 - 21	Fresh Breeze	Moderate waves, taking a longer form, many white caps, some spray, 2 m/6 feet



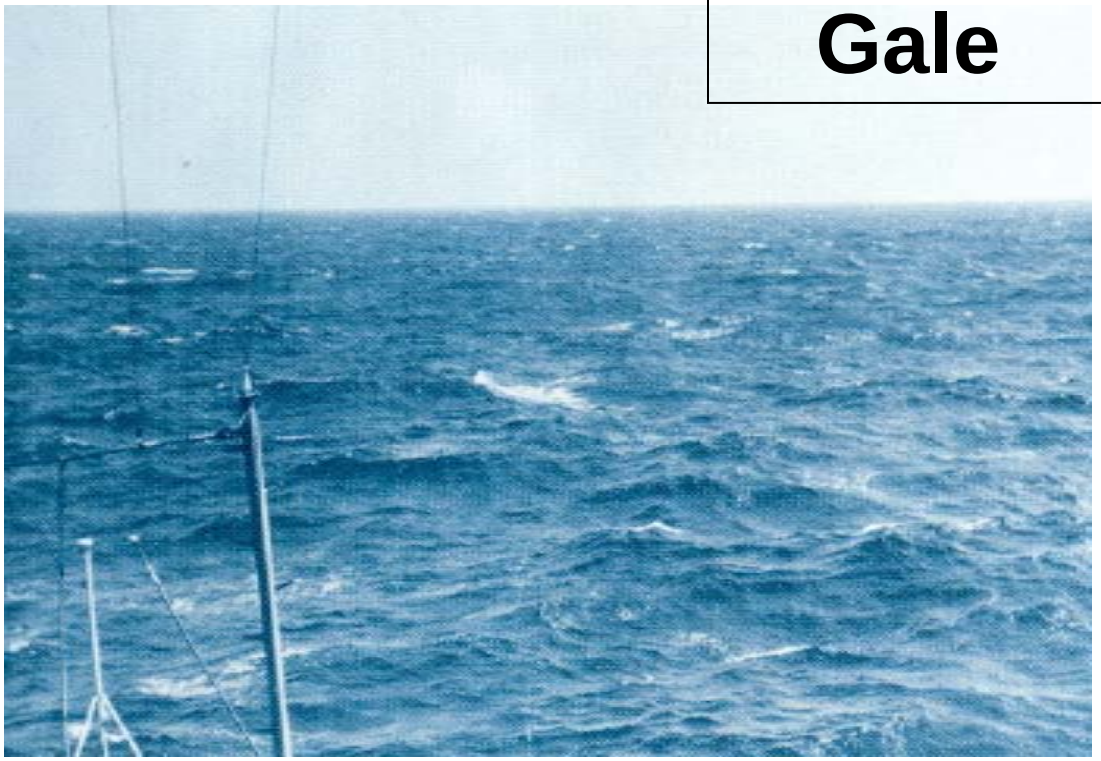
Force 6

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
6	22 - 27	Strong Breeze	Large waves forming, white caps everywhere, more spray, 3 m/10 feet



Force 7

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
7	28 - 33	Near Gale	Sea heaps up, white foam from breaking waves begins to be blown in streaks. 4 m/14 feet

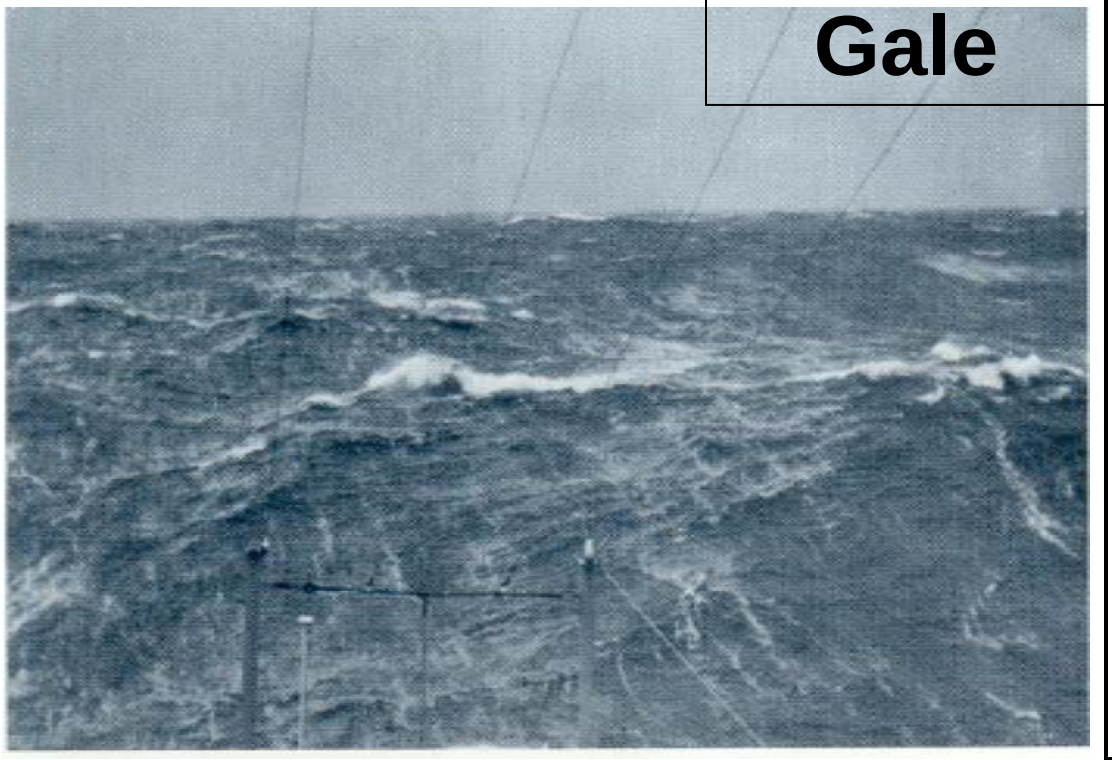


Force 8

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
8	34 - 40	Gale	Moderate high waves, greater length, tops begin to break into spindrift; foam is blown in streaks. 5 m / 18 feet

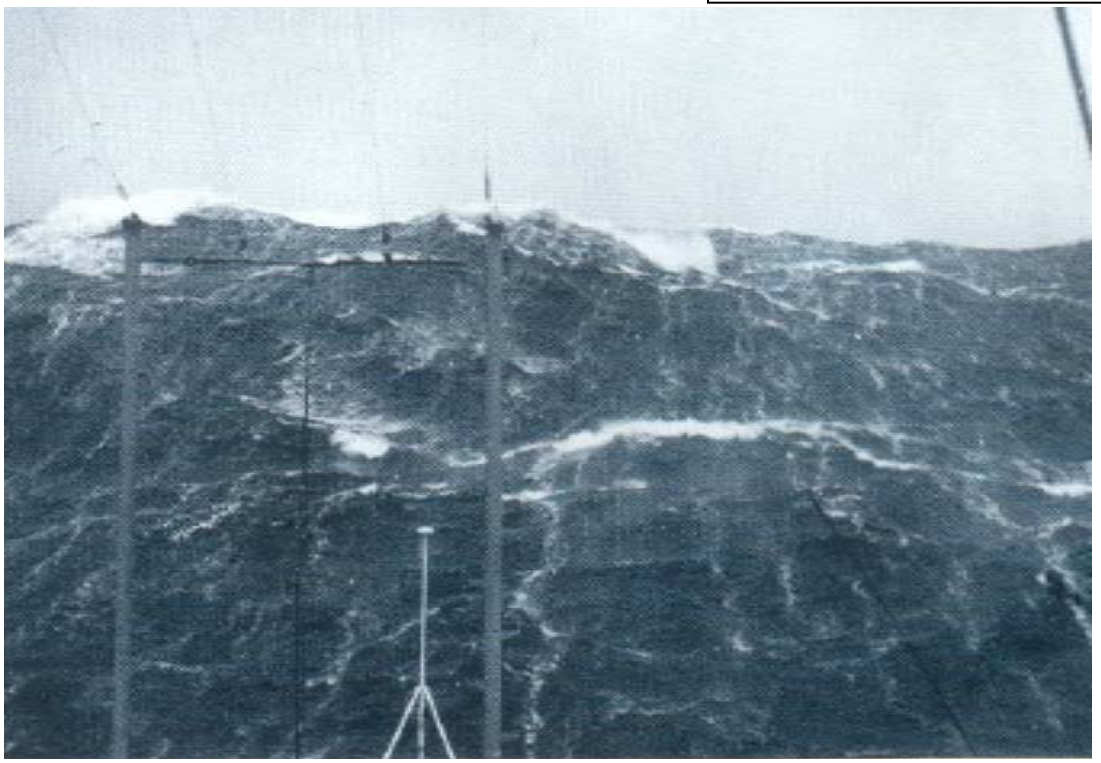
Force 9

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
9	41 - 47	Strong Gale	High waves; the sea begins to roll, dense streaks of foam; spray may reduce visibility. 7 m – 23 feet.



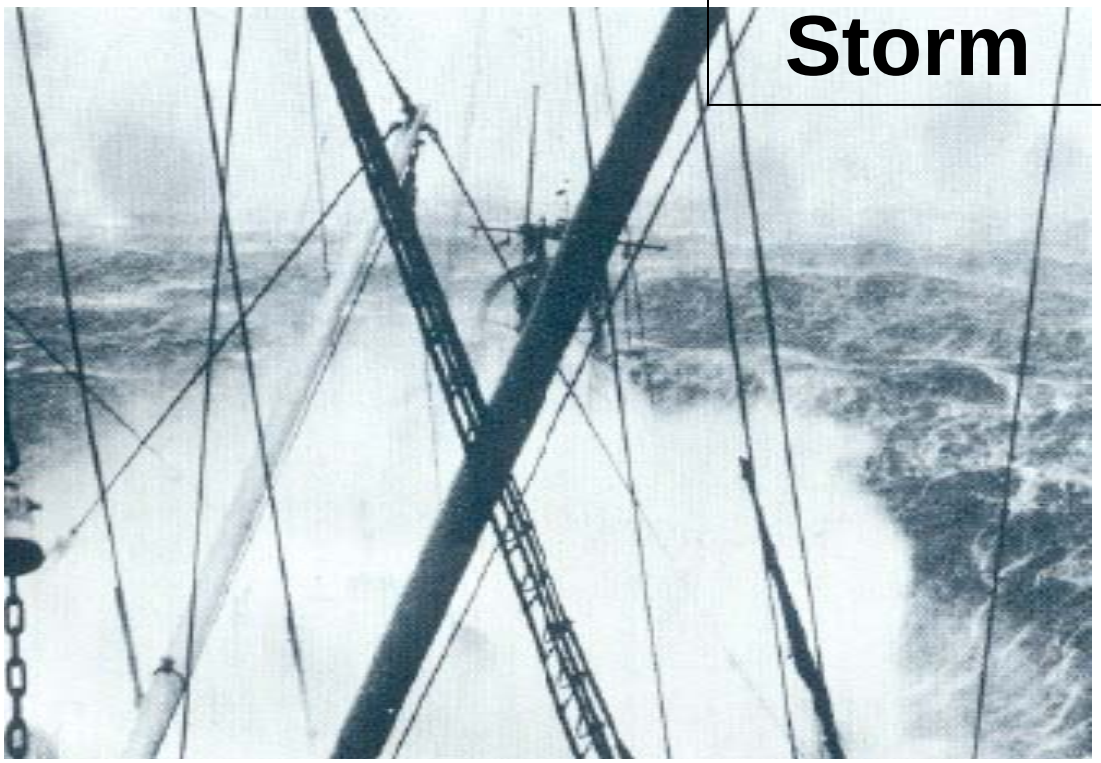
Force 10

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
10	48 - 54	Storm	Waves v-high; overhanging crests; white sea as foam is blown in very dense streaks; rolling heavy, visibility reduced. 9 m / 29 feet



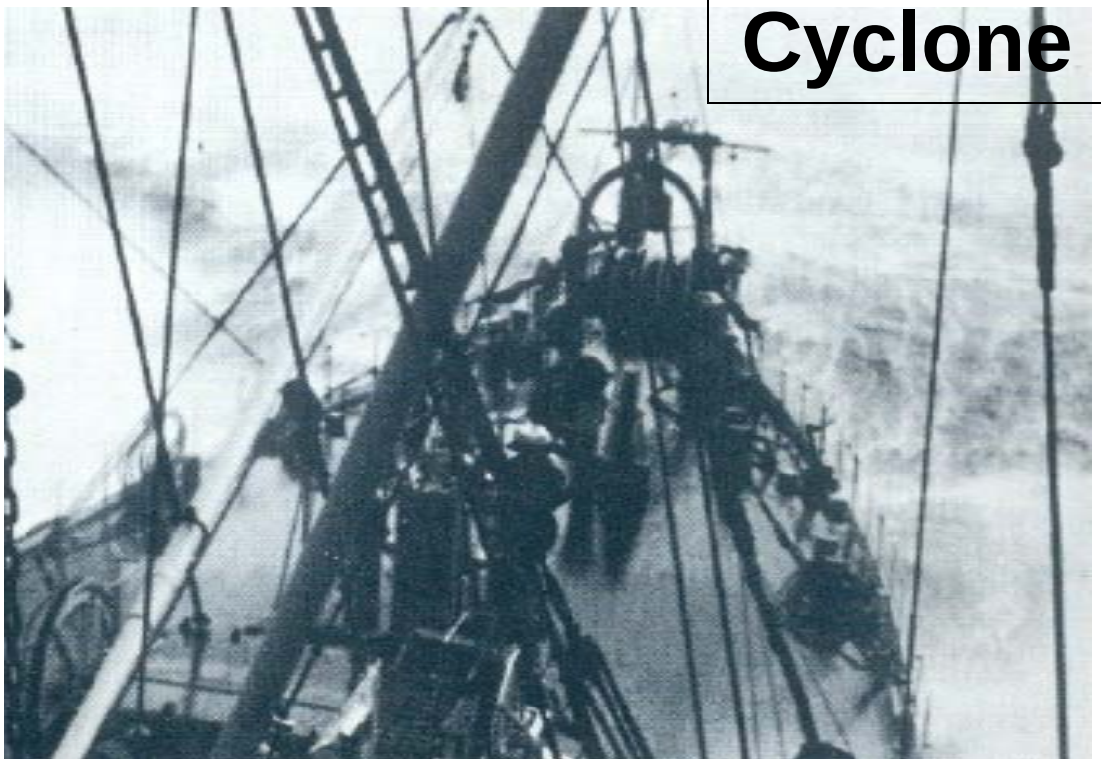
Force 11

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
11	56 - 63	Violent Storm	Exceptionally high Storm waves; sea covered with white foam patches; visibility still more reduced. 11 m / 37 feet.



Force 12

Beaufort Scale Number	Wind speed knots	Beaufort Name stated	Beaufort Sea State
12	64 +	Hurricane Cyclone	Air filled with foam. Sea completely white with driving spray; visibility Greatly reduced. 14 m / 45 feet.



Forces 12 to 17 as in the USA

Beaufort Force Number	Wind Speed (knots)	Beaufort Name	Beaufort Sea State
12	64 – 71	Hurricane	14 - 16 m
13	72 - 80	Hurricane	>16 m
14	81 - 89	Hurricane	>16 m
15	90 – 99	Hurricane	>16 m
16	100 – 109	Hurricane	>16 m
17	109 – 118	Hurricane	>16 m

Wind and Sea States may differ:

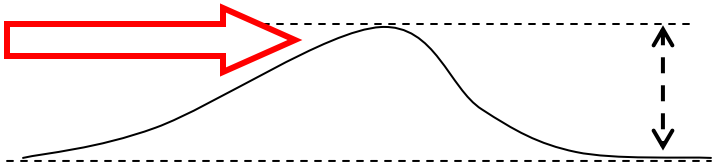
It is possible to have a sea state higher than the wind equivalent, or vice versa. For example, immediately after a storm which has ended rather quickly, the wind may drop to Force 5 while the sea state is still Force 7 but dropping soon.

AND, BE WARNED **… if the ocean current or a tidal stream is moving in the opposite direction to strong wind, a larger steep walled 'abnormal' wave develops. Yachts and ships can sink…**

Wave Patterns

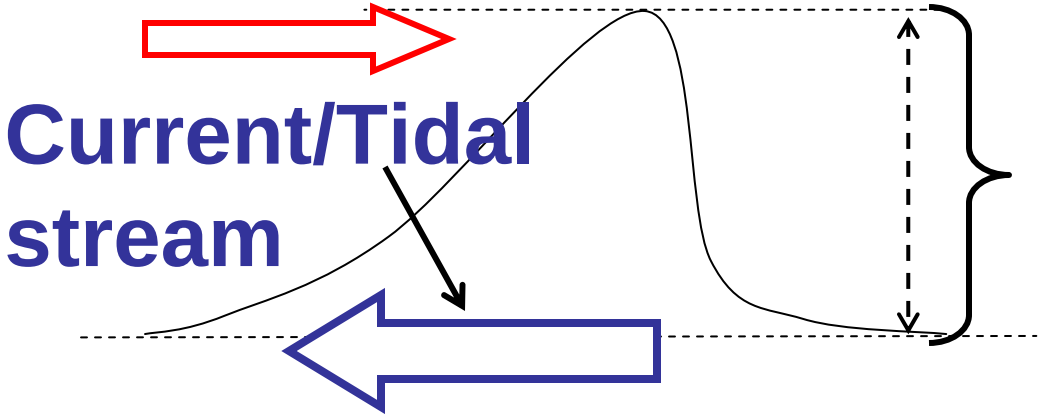
When wind at 30 to 40 knots

1. Normal wave patterns



+/- 4 m, no significant current or tidal stream

2. Abnormal wave patterns



If the current or tidal stream is +/- 2.5 to 5+ knots, the 'wall' is +/- 10 m*!*

When SW winds are on the South East coast of South Africa, this is normal*!!!*

Big waves are not straight nor perfectly parallel lines – there are areas where one crosses another, and 10 m + 10 m = 20 m!

A wall of a wave, 10 or 20 m high, will smash a yacht and 20 m capsize any ship which is ‘beam on’ (sideways on) to the approaching wave. And even if ‘head-on’ to that size wave, is like driving fast into a strong wall. There are ships and yachts, with people on board, that we know just disappeared wherever in areas where that type of wind against current occurs.

Cyclonic and Anti-Cyclonic Winds

Whether in the northern or southern hemispheres, ‘cyclonic’ winds are around ‘Lows’, and anti-cyclonic winds are around ‘Highs’, regardless of rotation direction.

Do not be confused – these names have nothing to do with meaning these winds are cyclones, Tropical Revolving Storms, TRS’s, etc. They just tell us that if wind is cyclonic, it is a Low; anti-cyclonic a High.

Low Pressures – Cyclonic Winds

We saw that High Pressure is anywhere where the sea level air pressure is greater than 1013 mbs – therefore less than that is a Low Pressure (L). L = <1013 mbs.

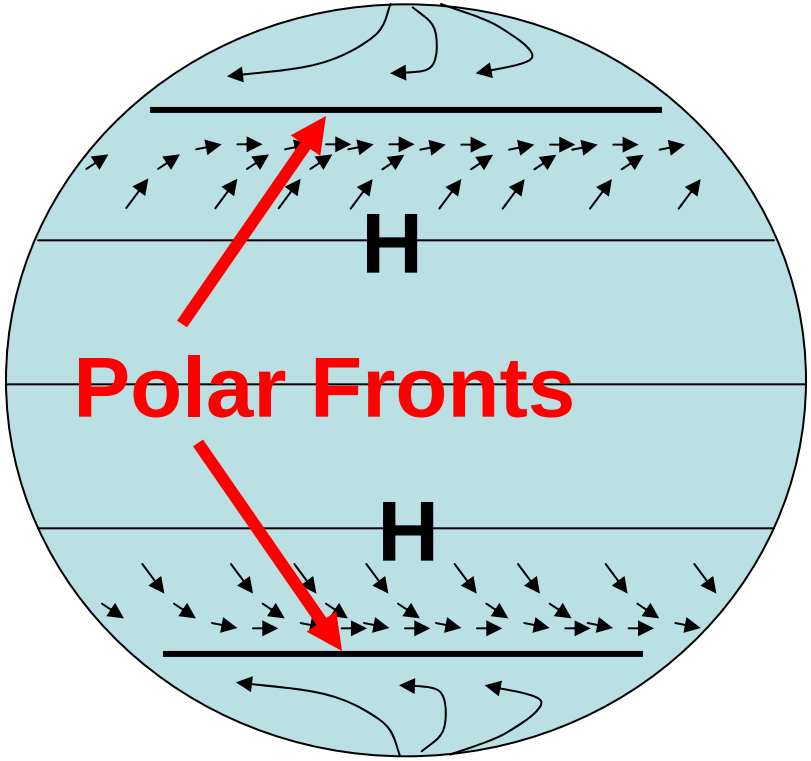
We are involved with three types of Lows:

1. **Ocean Low:**
    - **a. Formed at the Polar Front.**
    - **b. Formed close to the equator.**

2. **Coastal Low – formed on a coast line.**

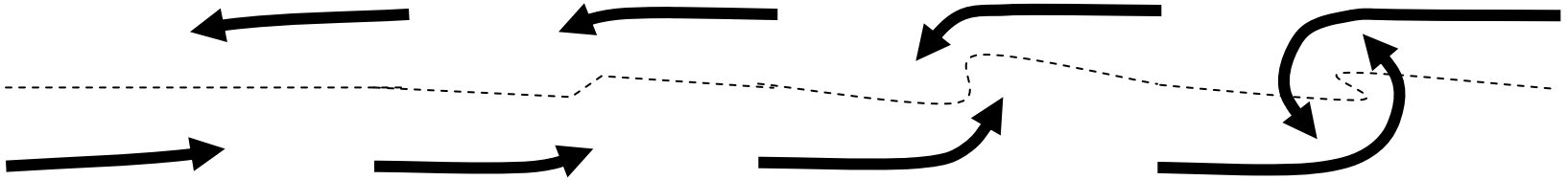
1.a. Ocean ‘Low’ at the Polar Front

At Polar Fronts there are the two winds blowing in opposite directions. Imagine what will happen if they get too close to each other! It will be like angry dogs circling around each other!!!



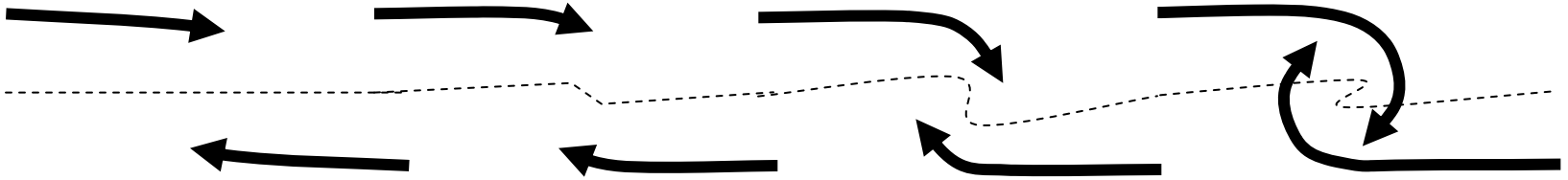
When the two strong winds begin to approach too close to the sides of each other, a spinning motion starts:

Northern Hemisphere Polar Front:



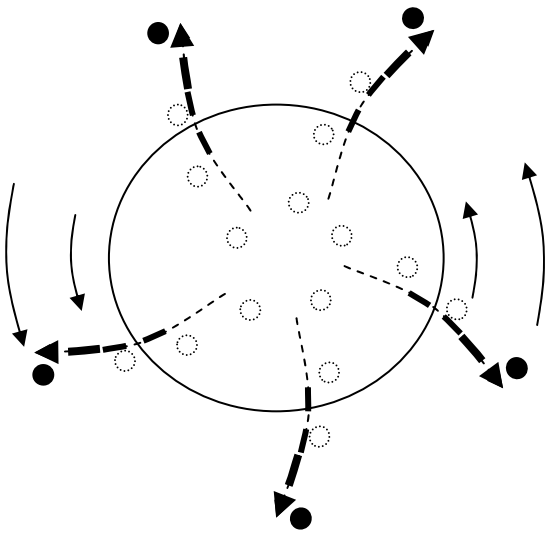
Anti-clockwise turning

Southern Hemisphere Polar Front:



Clockwise rotation

We know that if we had a plate with crumbs on it, and it was on a disc that spins, as it starts to turn the outer and lighter crumbs slide outwards and off the plate. As it speeds up, more and more crumbs do the same thing.

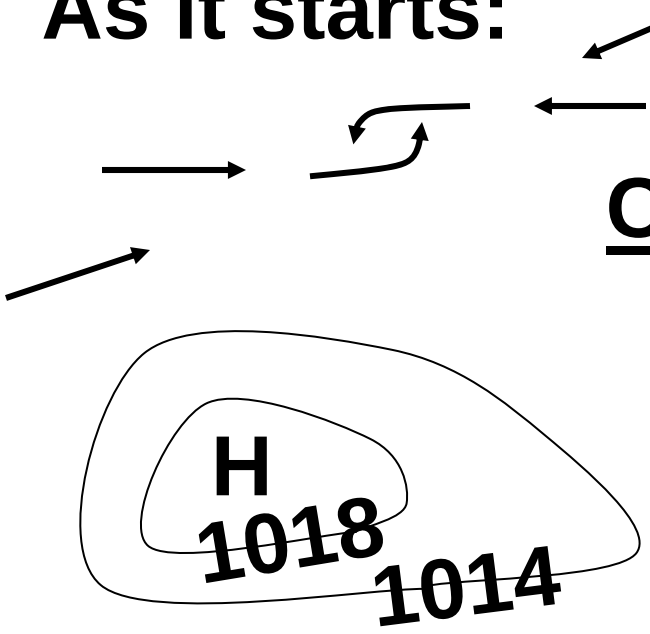


Look at water rushing out of a basin's outlet – as it speeds spinning, so a hole develops in the centre.

The faster the winds were blowing, the higher the speed of revolution forms, and the lower the pressure at the centre of the circle, the Low Pressure (L), becomes.

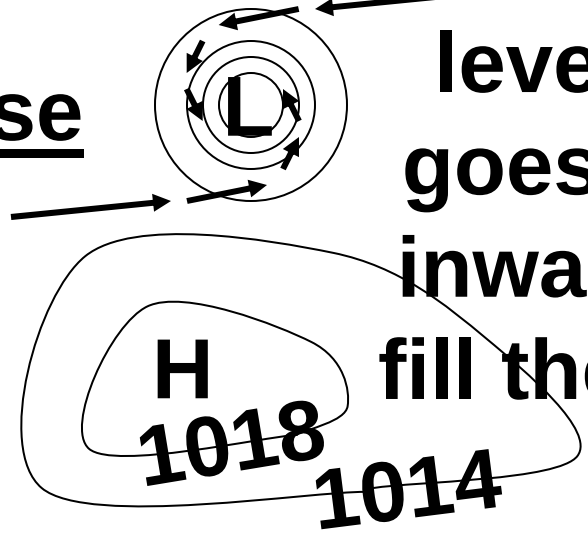
Northern Hemisphere:

As it starts:



Anti - Clockwise

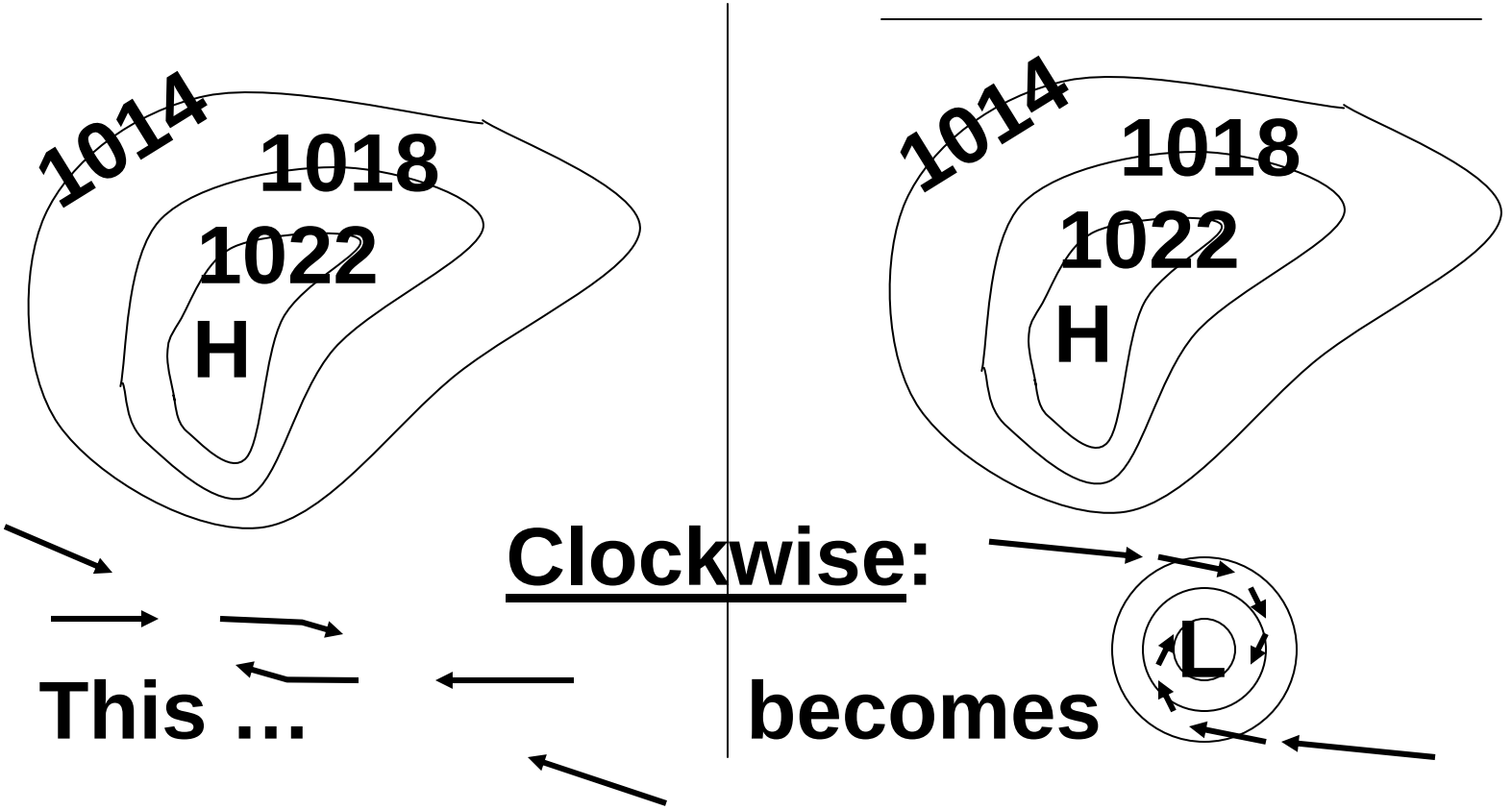
It becomes:



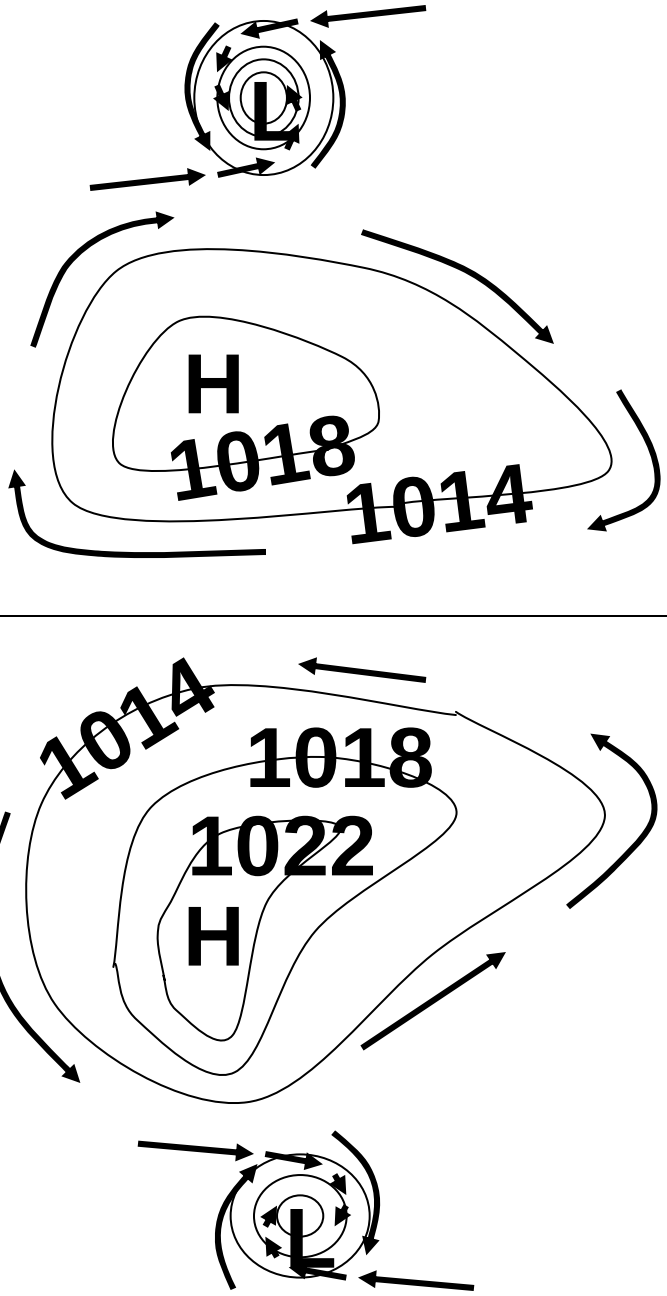
At sea level, air goes fast inward to fill the ‘L’.

Wind around a ‘Low’ in the southern hemisphere curves inward in a clockwise direction to fill the air gap being created.

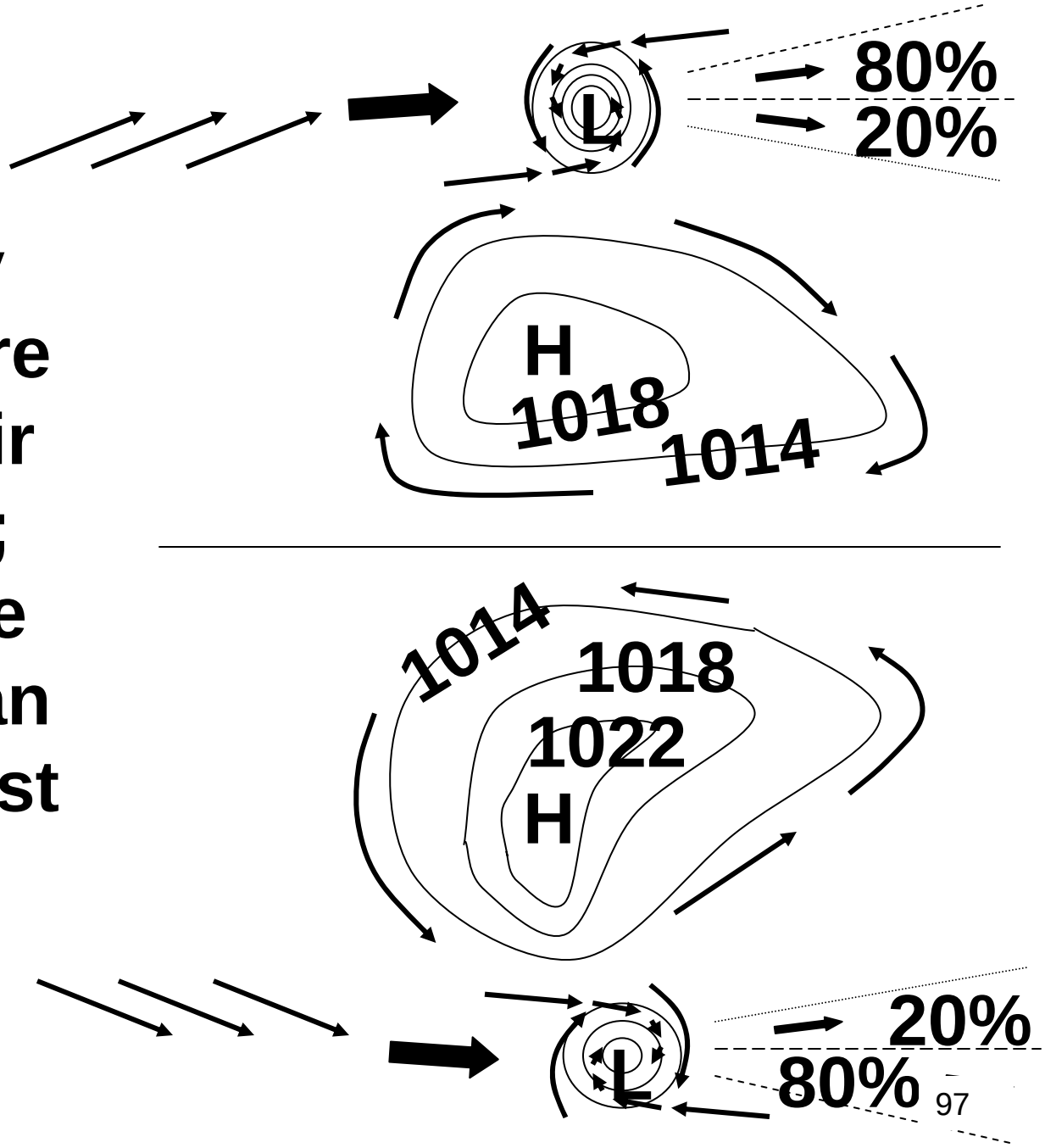
Southern Hemisphere:



So remember: ocean Lows are created in the Polar fronts, Lows in the north turn anti-clockwise; in the southern hemisphere they are clockwise. Highs rotate opposite to Lows.

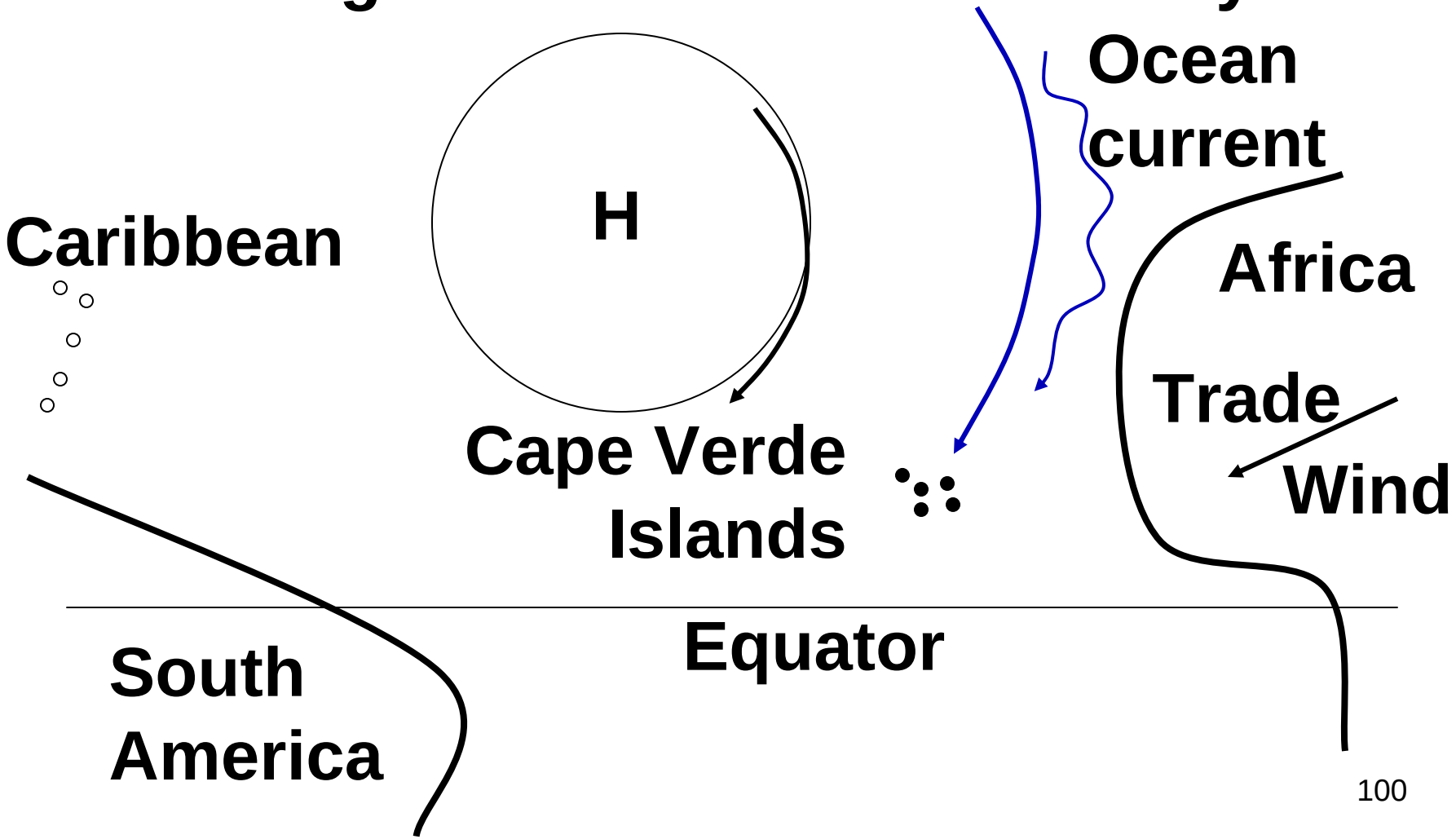


The westerly trade winds are always in their general area; they therefore push the ocean Lows from west to east.

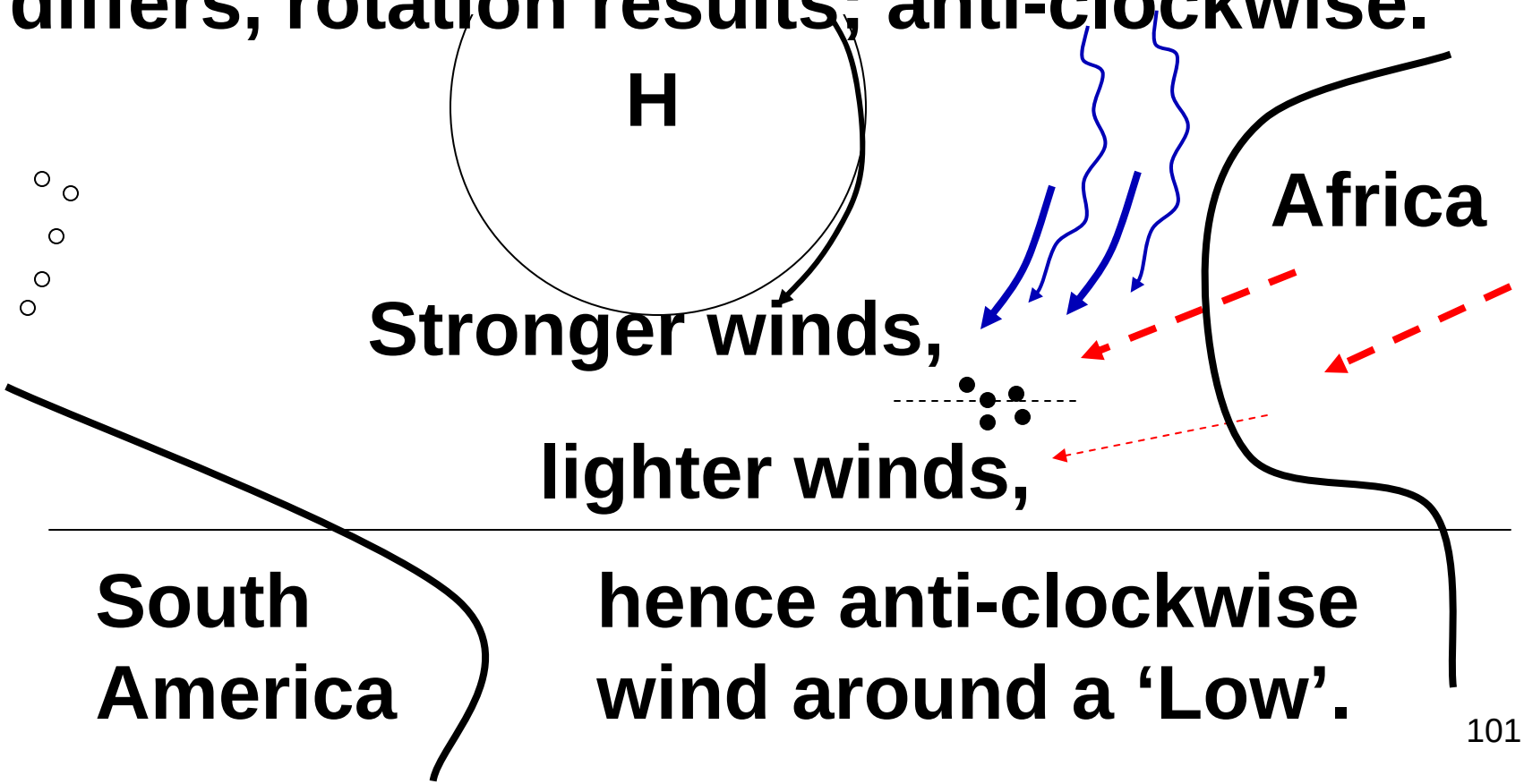


1.b. Ocean Lows form near the equator.

In the North Atlantic, cold wind from the Artic brings cold water the same way:



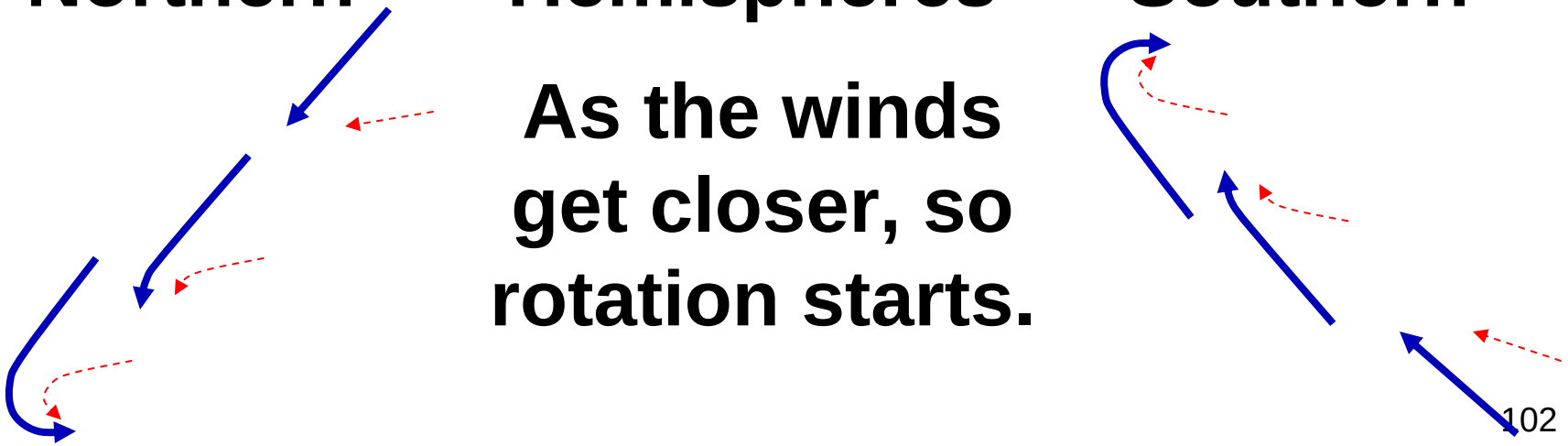
The relatively colder water causes cool air – cool air speeds up as it approaches the gap of rising hot air over these islands. When the occasional Trade winds speed differs, rotation results; anti-clockwise.



‘Anti-clockwise’ in the northern hemisphere is …
clockwise in the southern hemisphere!
These equator’s ‘Lows’ result from different wind speeds:

Faster anti-cyclonic wind →
Slower Easterly Trade wind ⇢

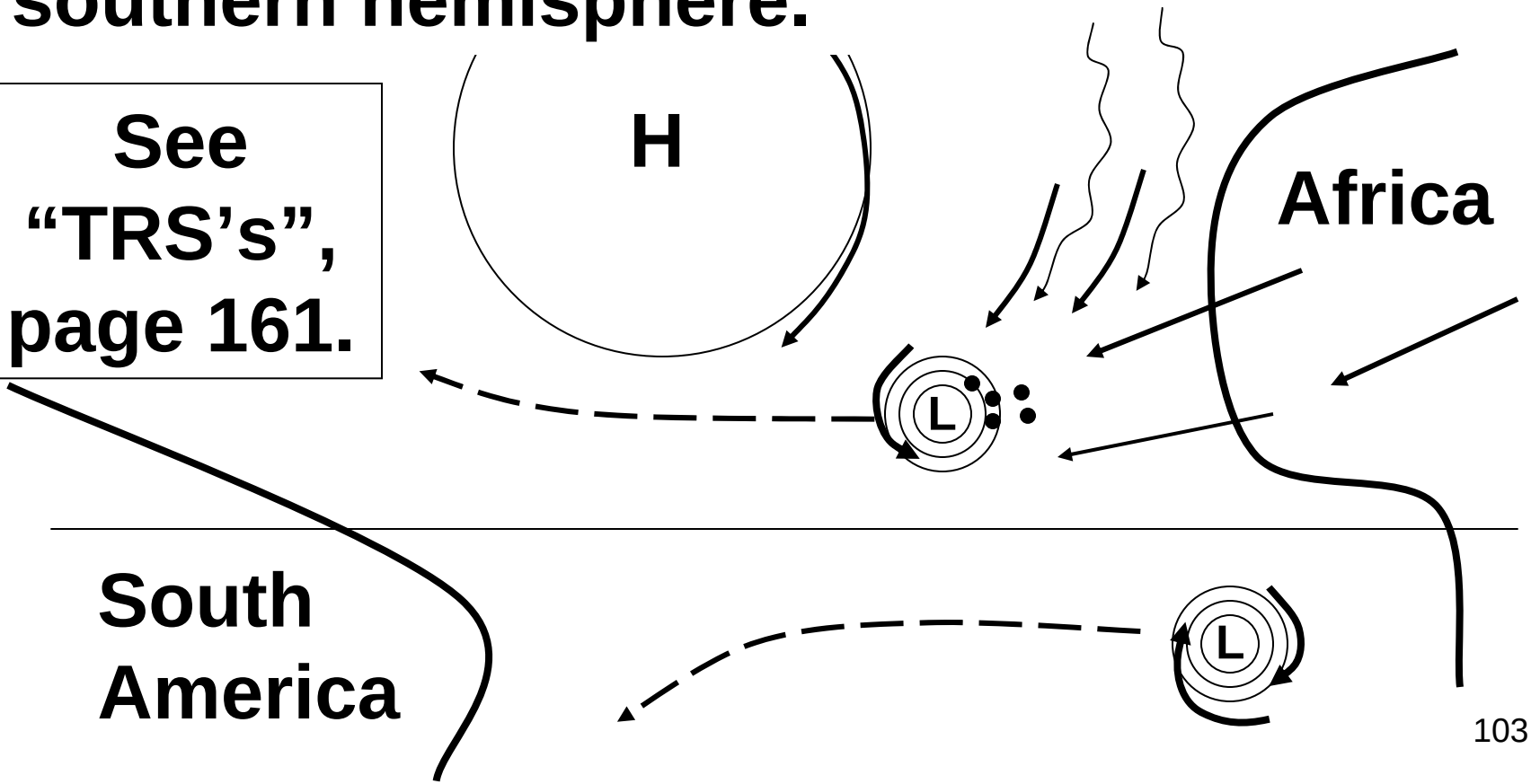
Northern Hemispheres Southern



As the winds get closer, so rotation starts.

Due to the stronger winds as well as the Easterly Trade Winds, once formed the Low is moved east to west. The same occurs in all oceans – mirror image for southern hemisphere.

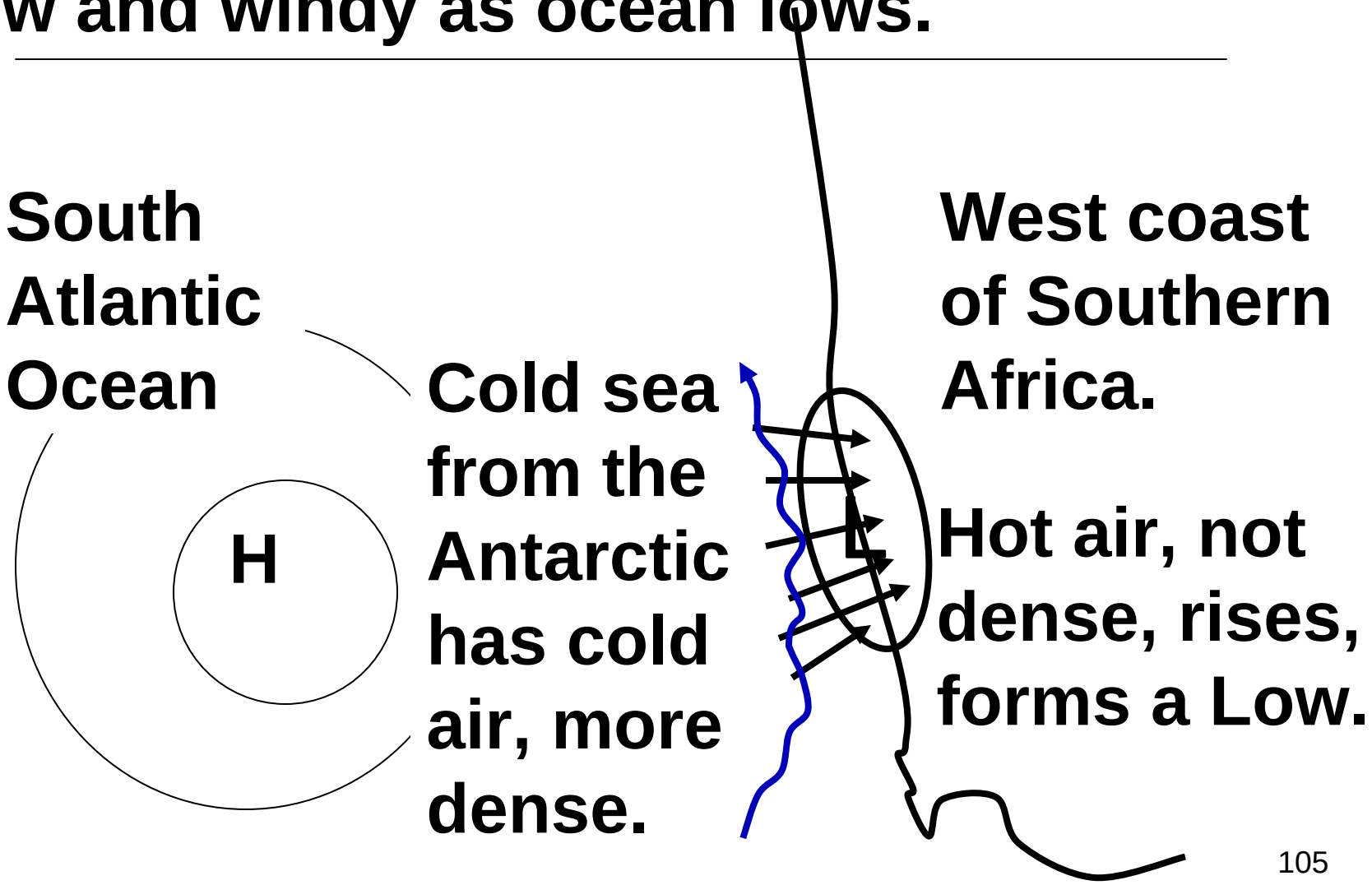
See "TRS's", page 161.



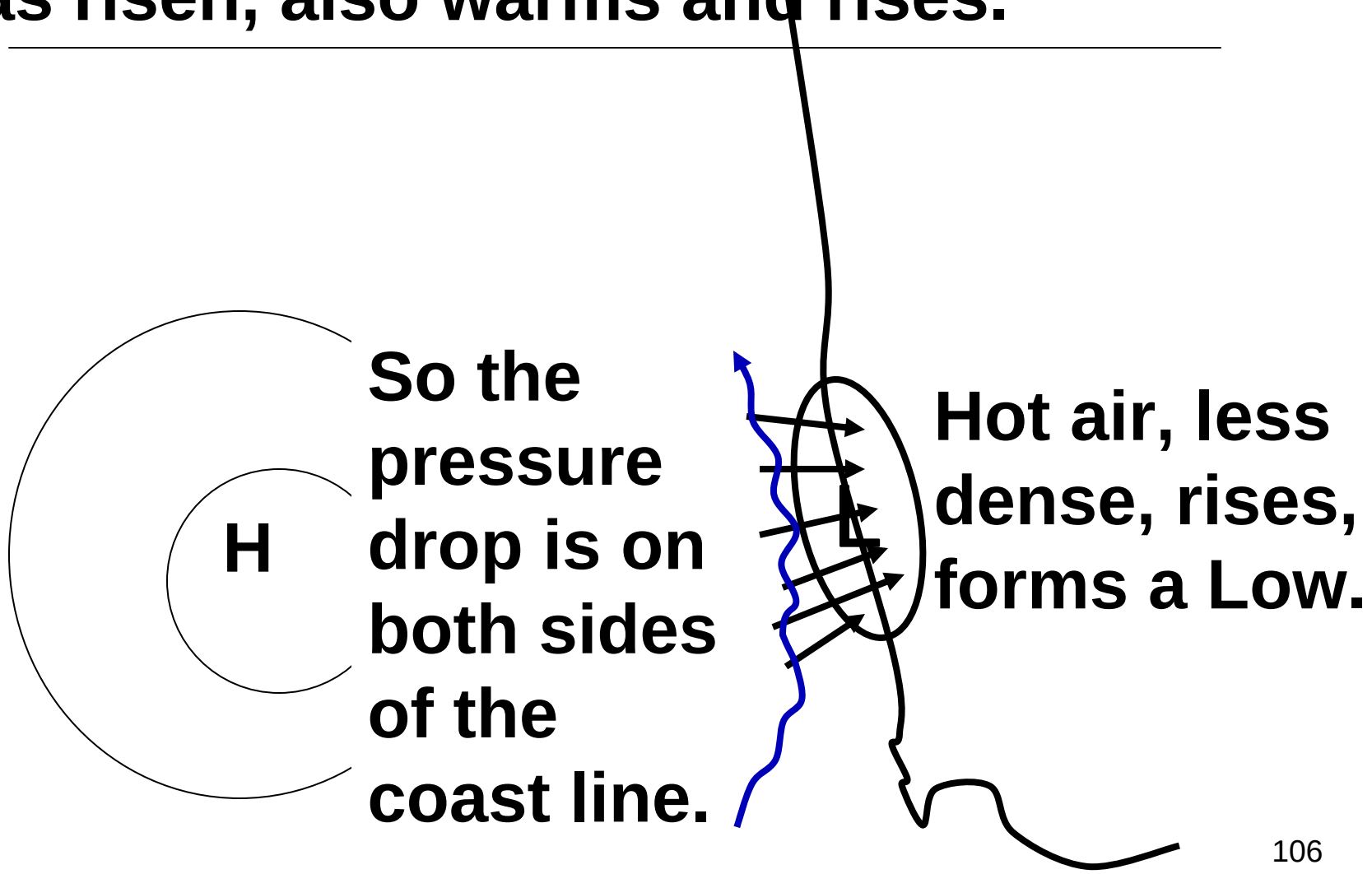
2. Coastal Lows

Where the land along a hot coastline has air rising, air over the colder sea does not; not all air rises. So the rising land air leaves a gap – a low pressure. Cold air moves in from the colder sea to fill the gap, and the more that goes ashore and heats up then rises, the more the air pressure across the coast-line drops.

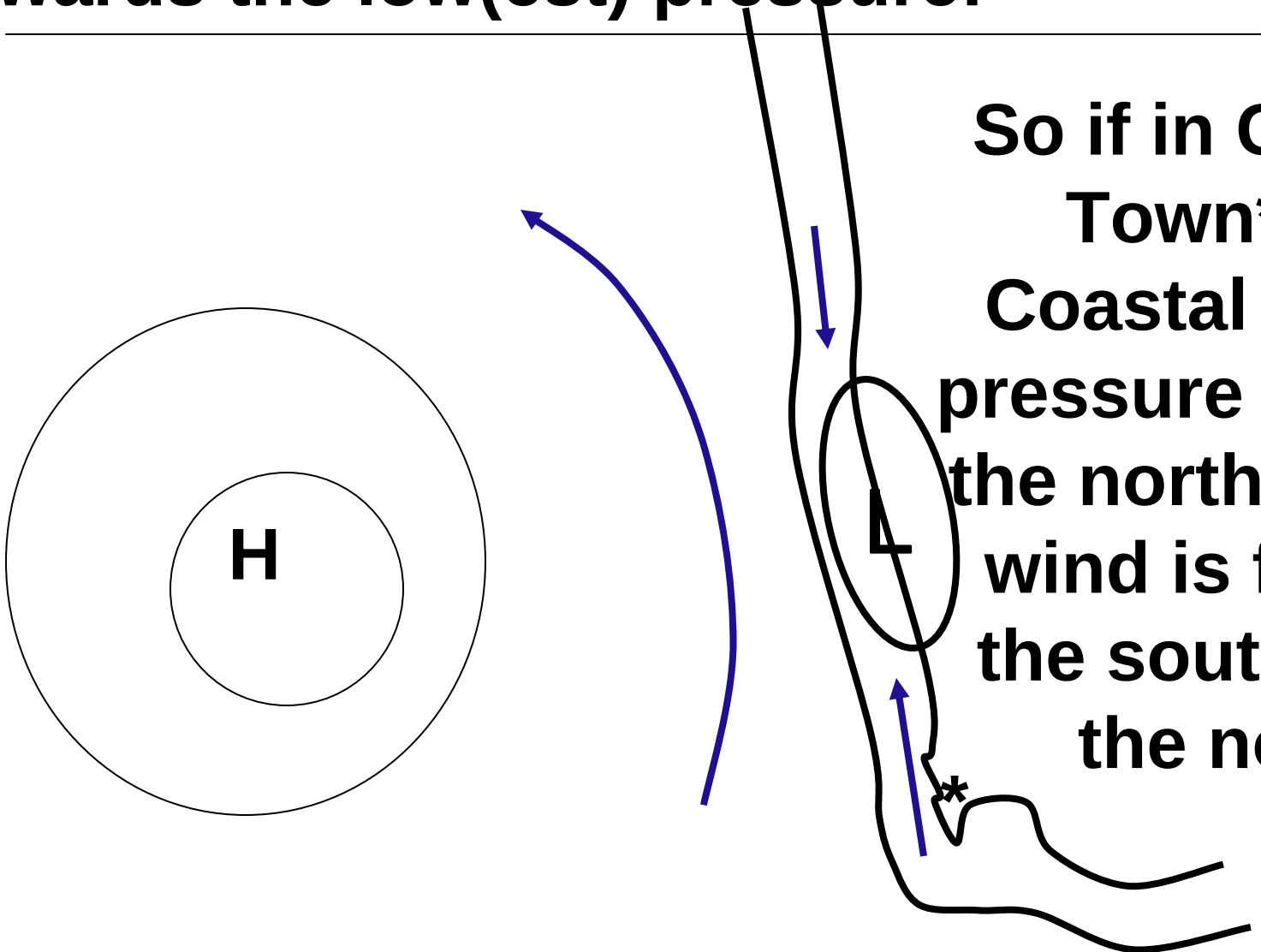
Southern Africa's west coast is an example of a coastal low. They are not as low and windy as ocean lows.



The cold sea air moving off the sea into the gap created by the hot land's air that has risen, also warms and rises.

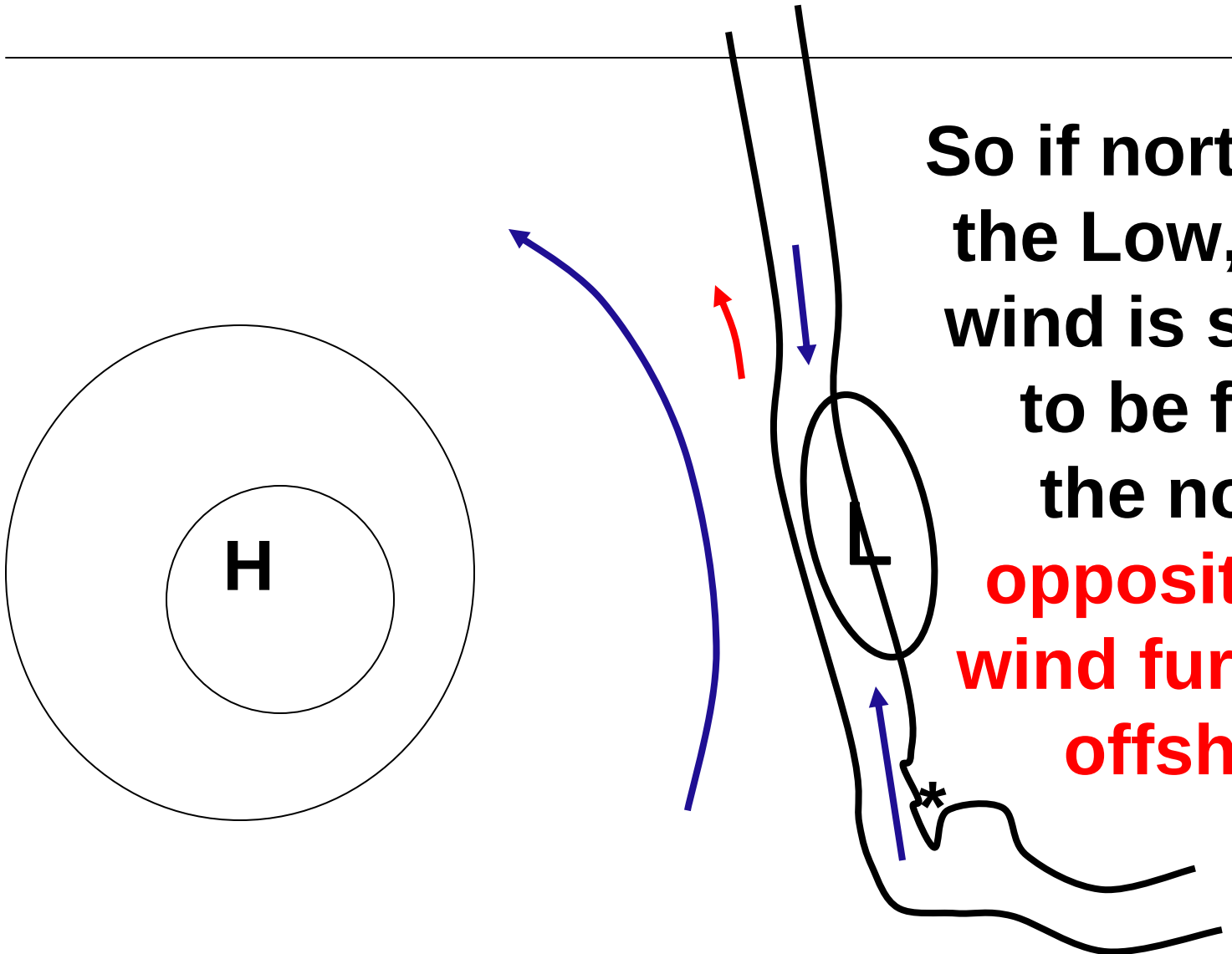


For +/- 50 n.m. seaward, the wind blows ‘80%’ of the time parallel to the coast towards the low(est) pressure:



So if in Cape Town* the Coastal Low pressure is to the north, the wind is from the south, to the north.

Weather forecasts refer to “Coastal Weather for 50 n.m. Seaward”:



So if north of the Low, the wind is seen to be from the north, opposite to wind further offshore.

Cold Fronts

and Warm ones!

We have all heard the term "Cold Front" and we know it relates to a temperature drop, cloudy cold weather, and rain.

We now know 'ocean lows' (1.a., pages 93 to 99) formed at the Polar Front are drawing in cold wind from the pole, and the Highs' warm humid air is formed near the equator. These two come together and then this happens …

Condensation, Coalescence, and Precipitation

When the faster cold air from an ocean Low happens to be where it runs into the back of slow moving warm humid air, there is cooling and condensation, forming many types of clouds, then coalescence results in precipitation – rain.

The greater the cold and humid warm airs' temperatures differ, the stronger the rain and wind increases. Now read …

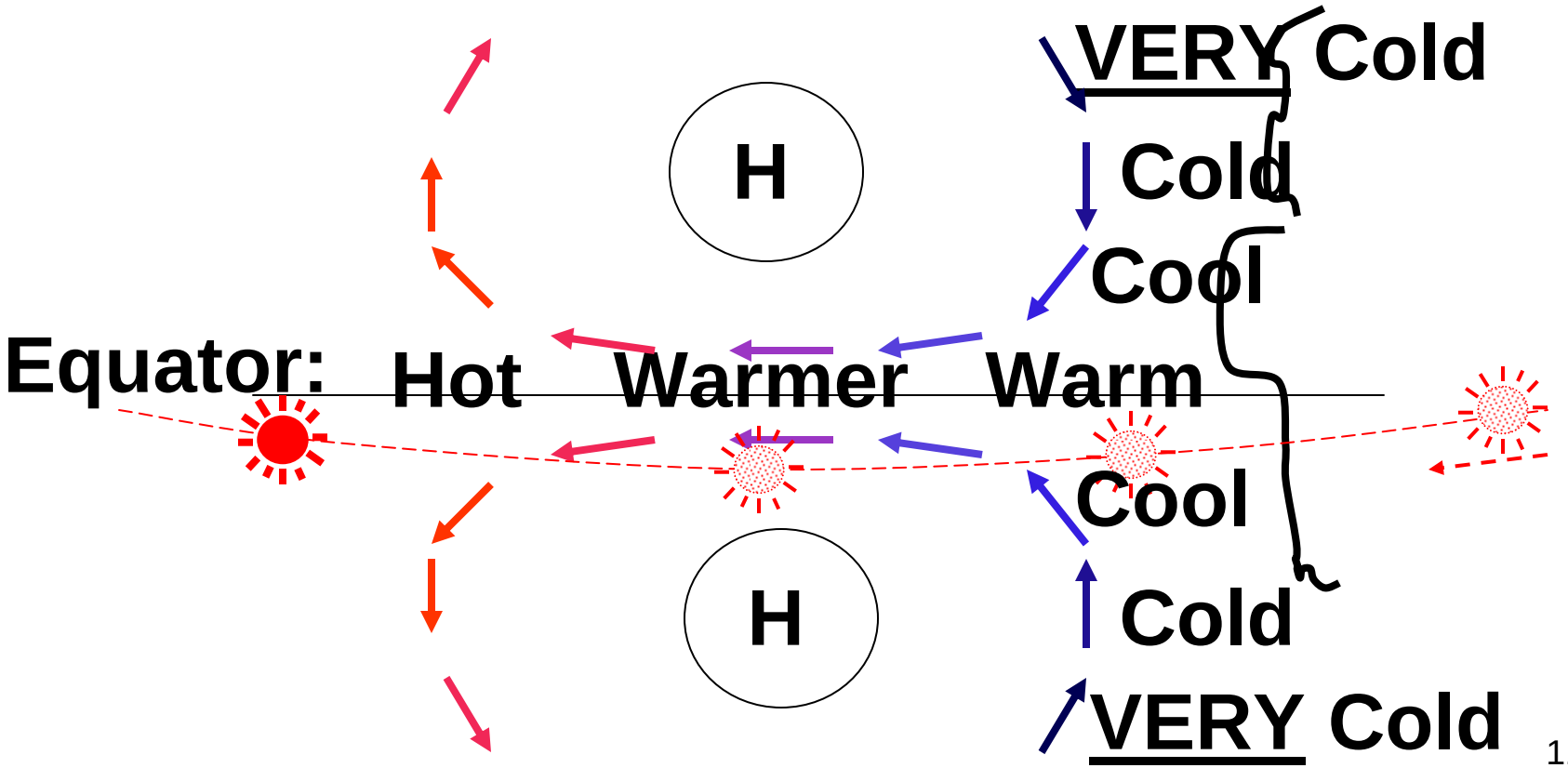
So what is:

<u>Condensation</u> – when humidity reaches 100%, Due Point, and then gets cooler, it has too much water vapour– some must go! Tiny drops of water, too light to drop, form and when many, they are seen as a cloud.

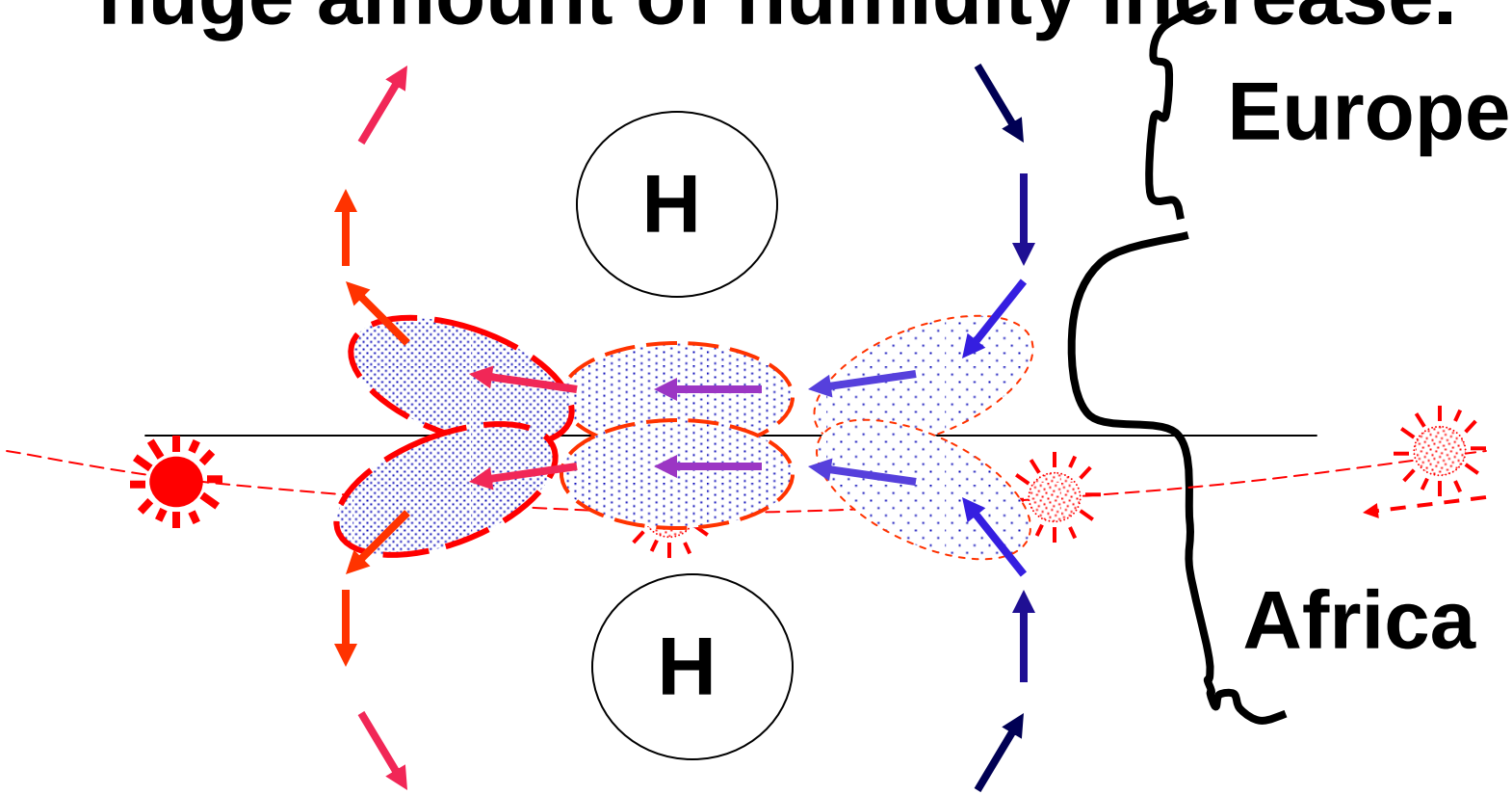
<u>Coalescence</u> – is when lots of the tiny drops bump into each other and join into bigger lumps of water, too heavy as clouds.

<u>Precipitation</u> – when these larger lumps, or drops, being heavy, fall downward – rain!

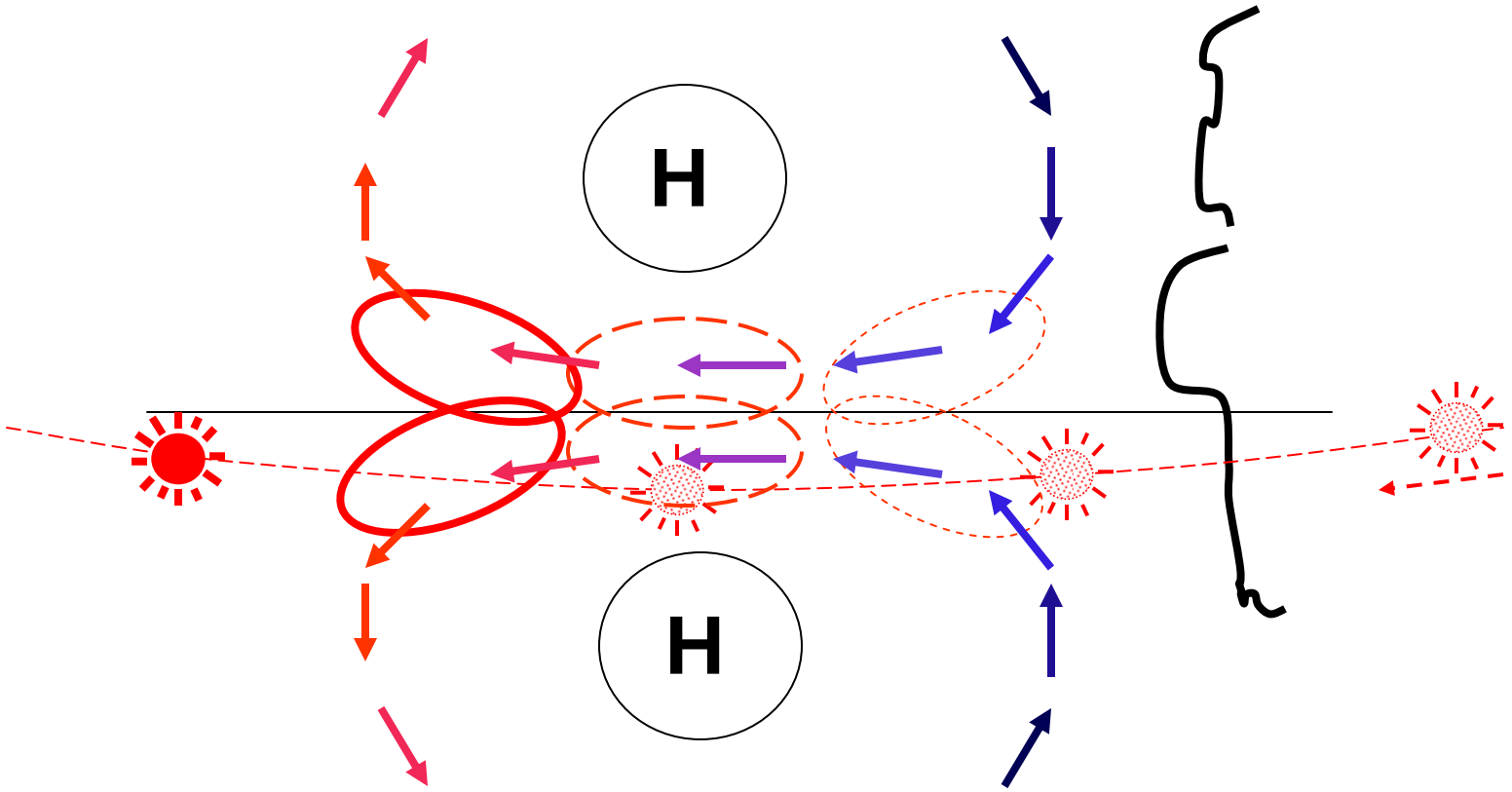
Cold water and cool air approach the equator on the east side of an ocean. As it moves towards the west it gets hotter by day as the sun moves across with it.



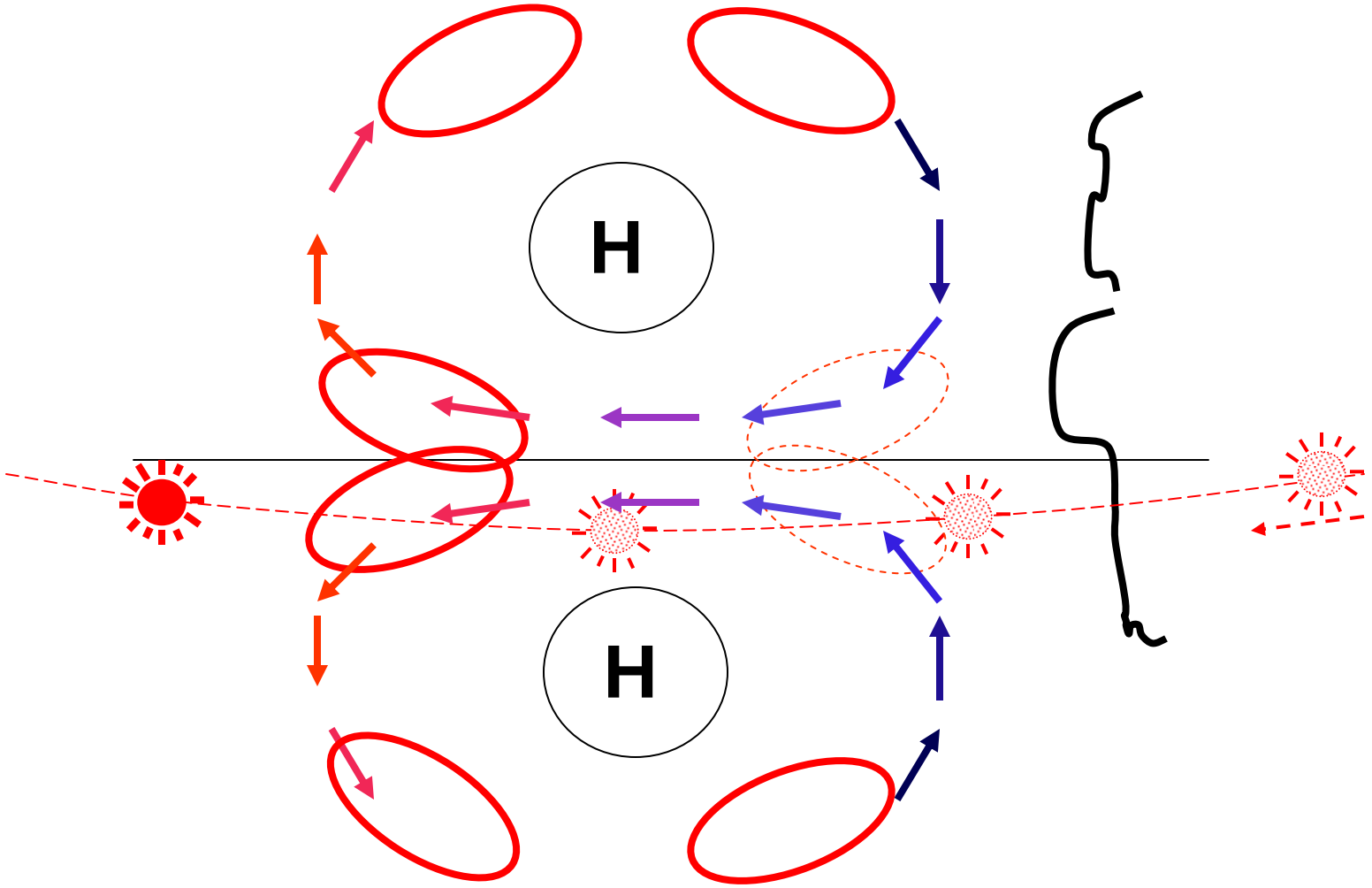
Each day as the sun rises, the sea and air start warming more near the equator, so evaporation starts and increases, and by the end of the day there has been a huge amount of humidity increase.



From sunrise to sunset every day we get an area of hot air created

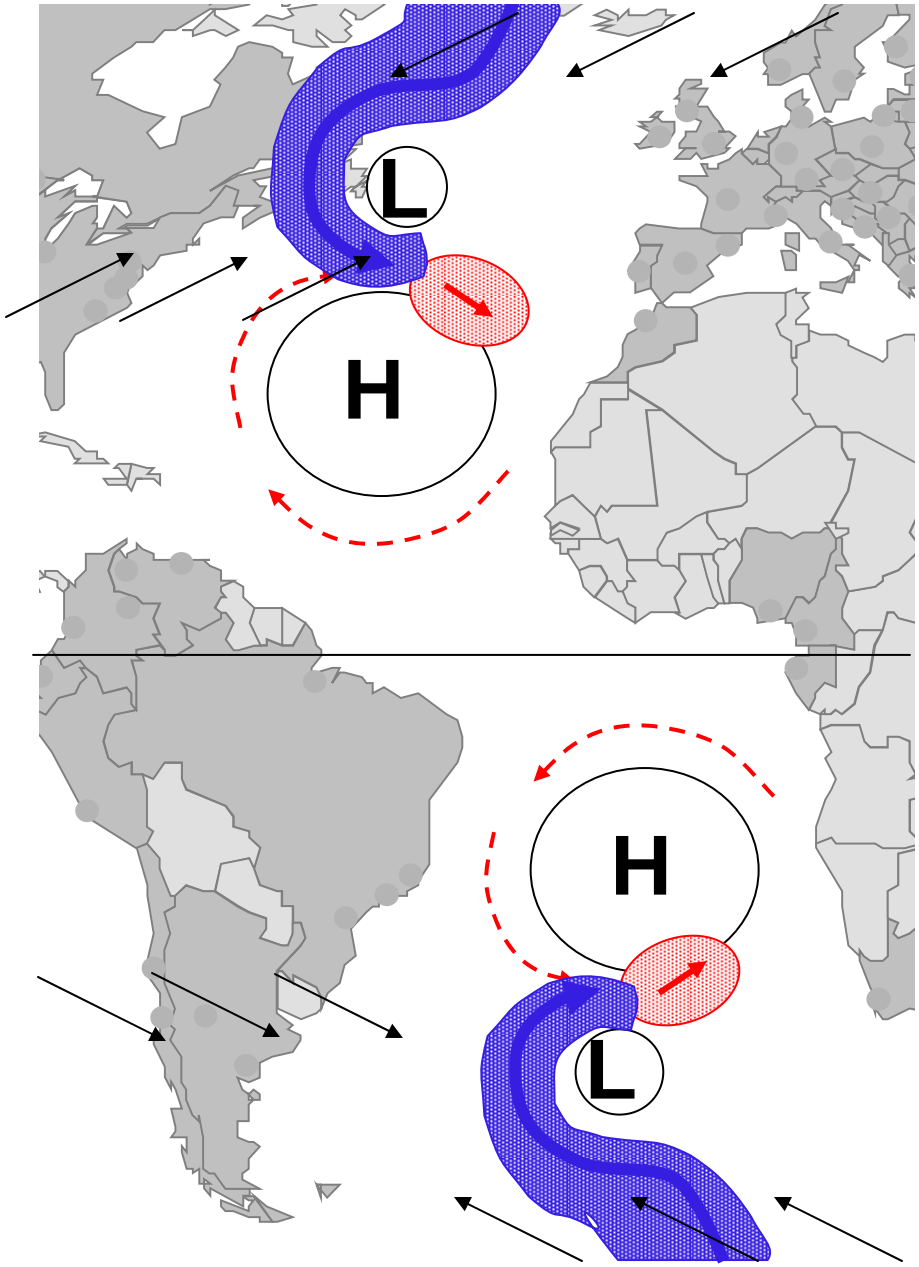


– at night it moves away, and the next day it repeats.



Now imagine (1) a day's humid hot air moves slowly around to the polar side of a High. When there, if an ocean Low which has formed and is moving faster, west to east due to the more powerful trade winds, and catches up with the back of the slow moving humid hot air, the cold air pushes hot humid air (2) - see the next page.

The humid air is cooled. Condensation is followed by Coalescence and Precipitation – a large temperature difference causes LOTS of this, and wind speed increases ...

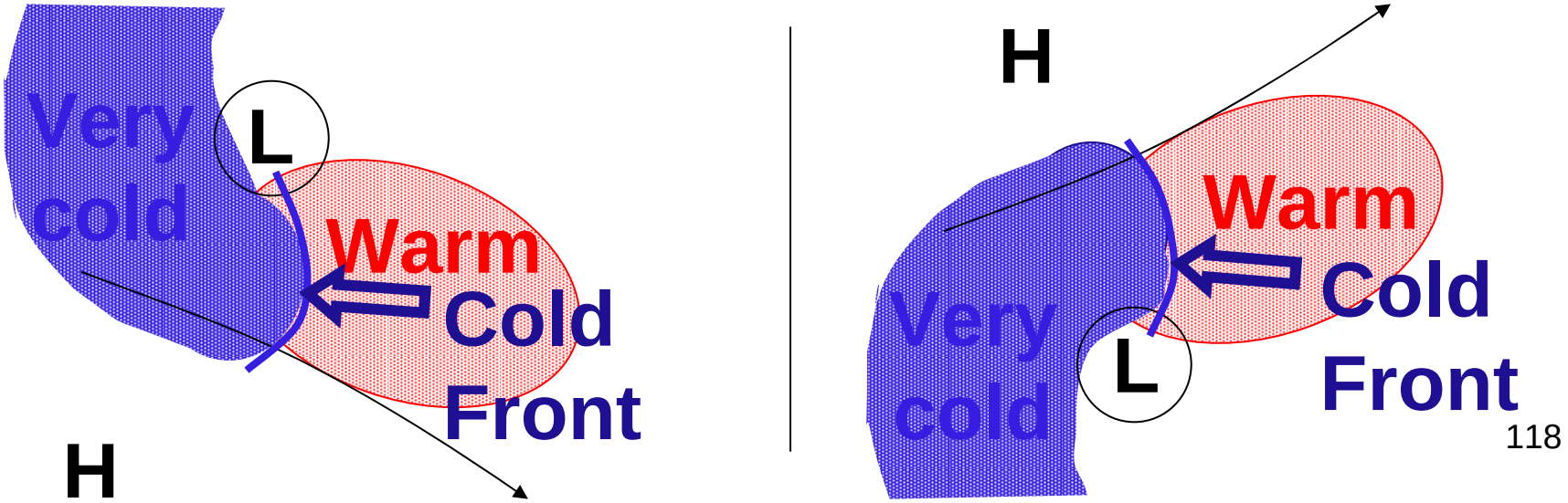


1. We see the slow **warm humid air** is on the polar side of the ‘High’.

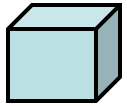
2. The ocean ‘Low’ has formed, and is pushing **fast cold air** into the back of the slow east moving warm humid air.

The airs' temperatures differences where the very cold polar wind pushes into the back of the warm, humid air, results in a huge amount of condensation, heavy rain and strong wind. When exceptionally strong from intense condensation, there may also be lightning, thunder and hail.

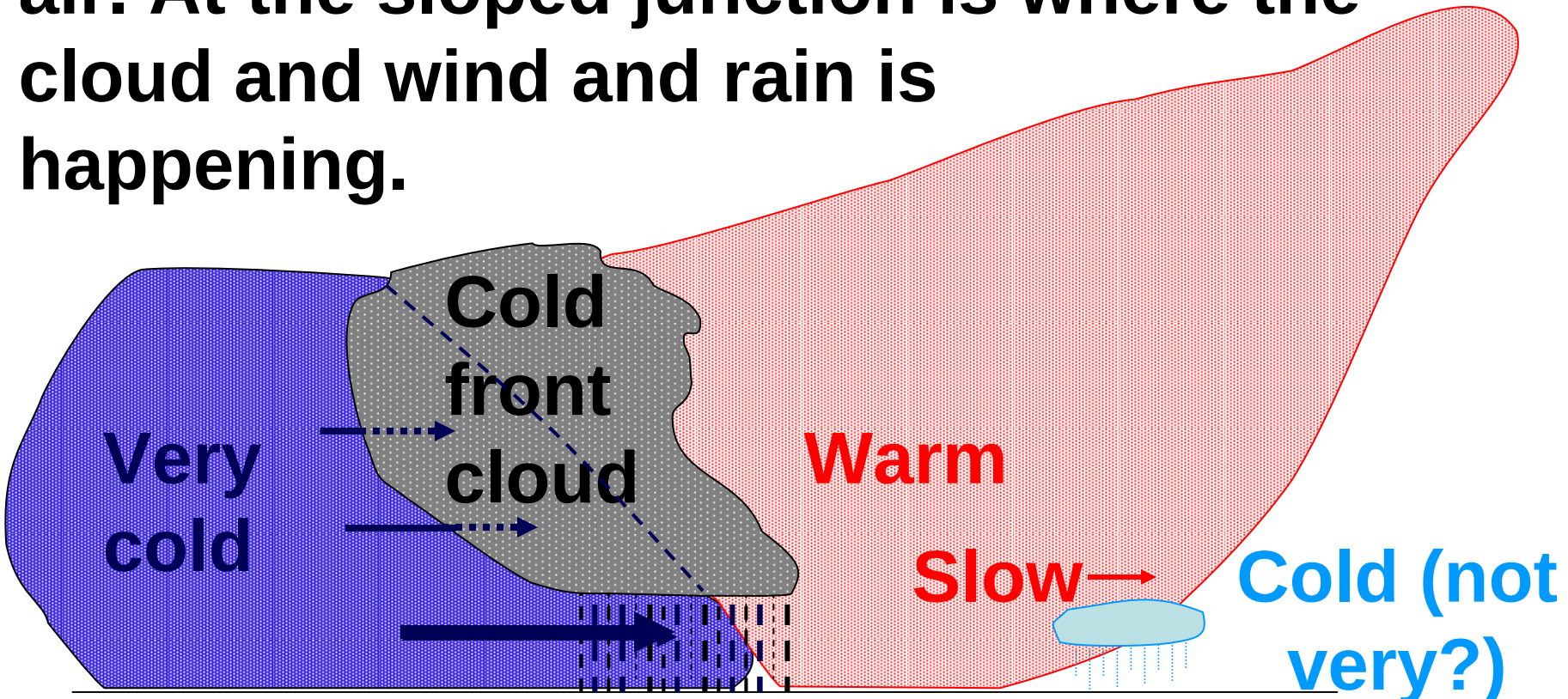
Northern Hemisphere Southern



This condensation, forming clouds as the cold front, creates rough winds following the big drop in air pressure. It causes wind speeding up to go into the cloud to fill the lost space once occupied by vapour.

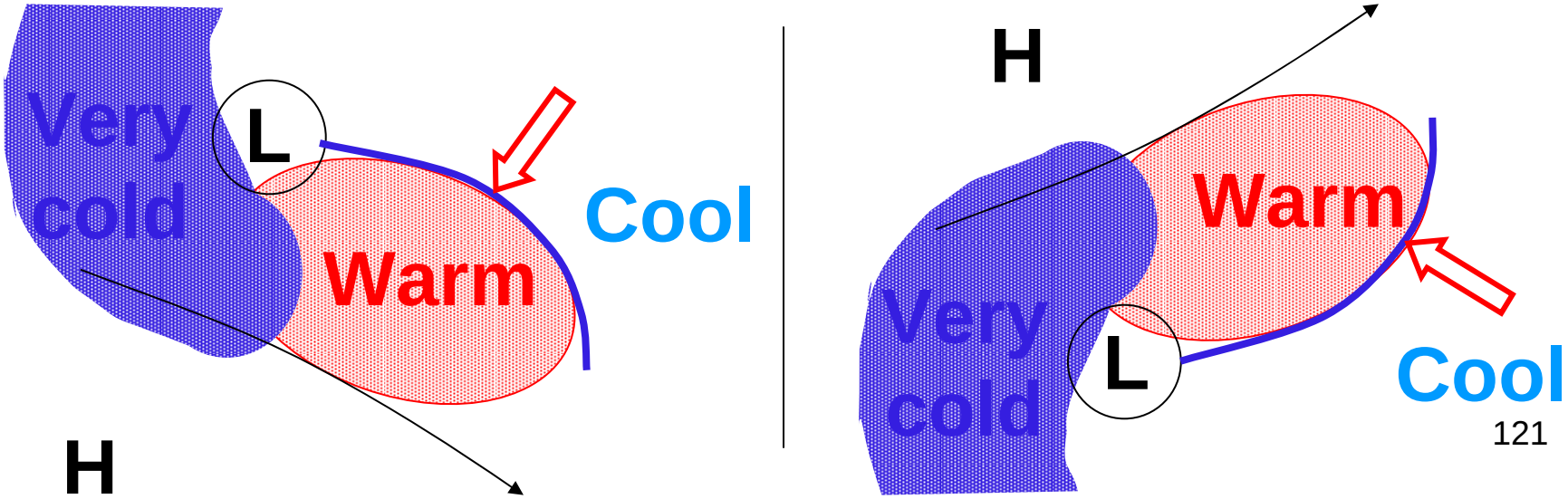
Assume this volume of vapour,  **, after condensation, forms a minute drop of water this size:** ◦ **. See how much space is left empty! So the pressure drops a lot. As this is happening in random areas, wind is moving in all directions in the Cold Front cloud – a VERY rough in-cloud wind ...**

Going from left to right, west to east, is the same in both hemispheres – the faster, heavier cold air pushes in under the warm air. At the sloped junction is where the cloud and wind and rain is happening.



If the air ahead of the 'front' of the warm air is cool, there *may* also be some dark condensation (clouds), coalescence, and then precipitation. However, this cool air is not as cold as the cold polar air; this rain and wind will not be as strong. It is the "Warm Front" ⇦ :

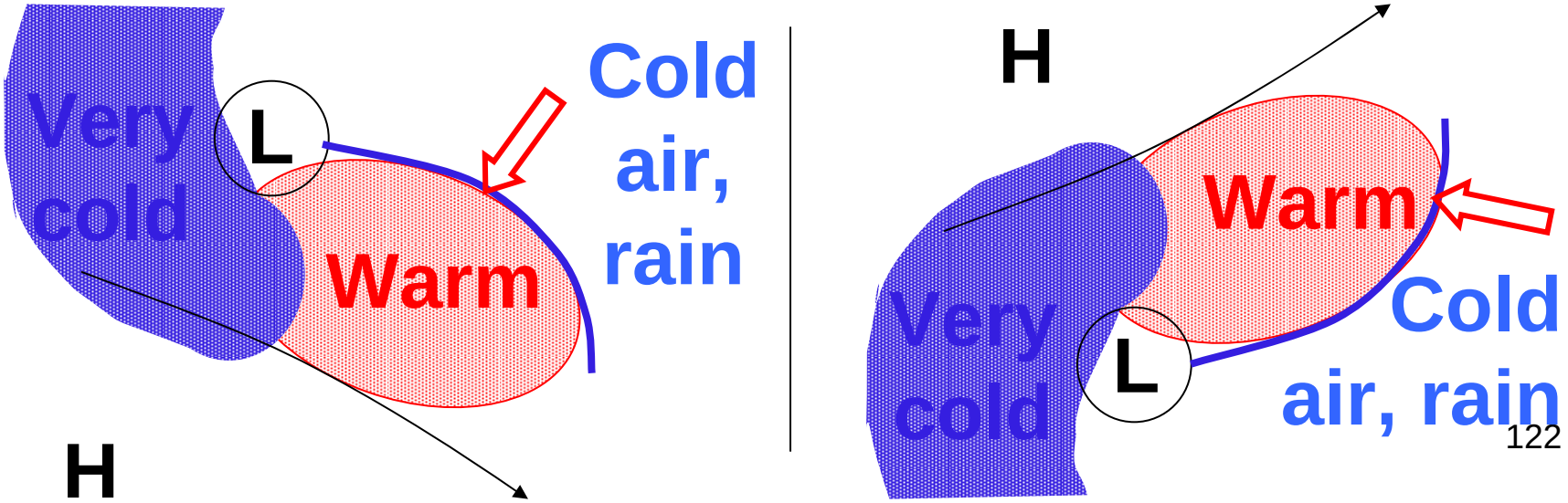
Northern Hemisphere Southern



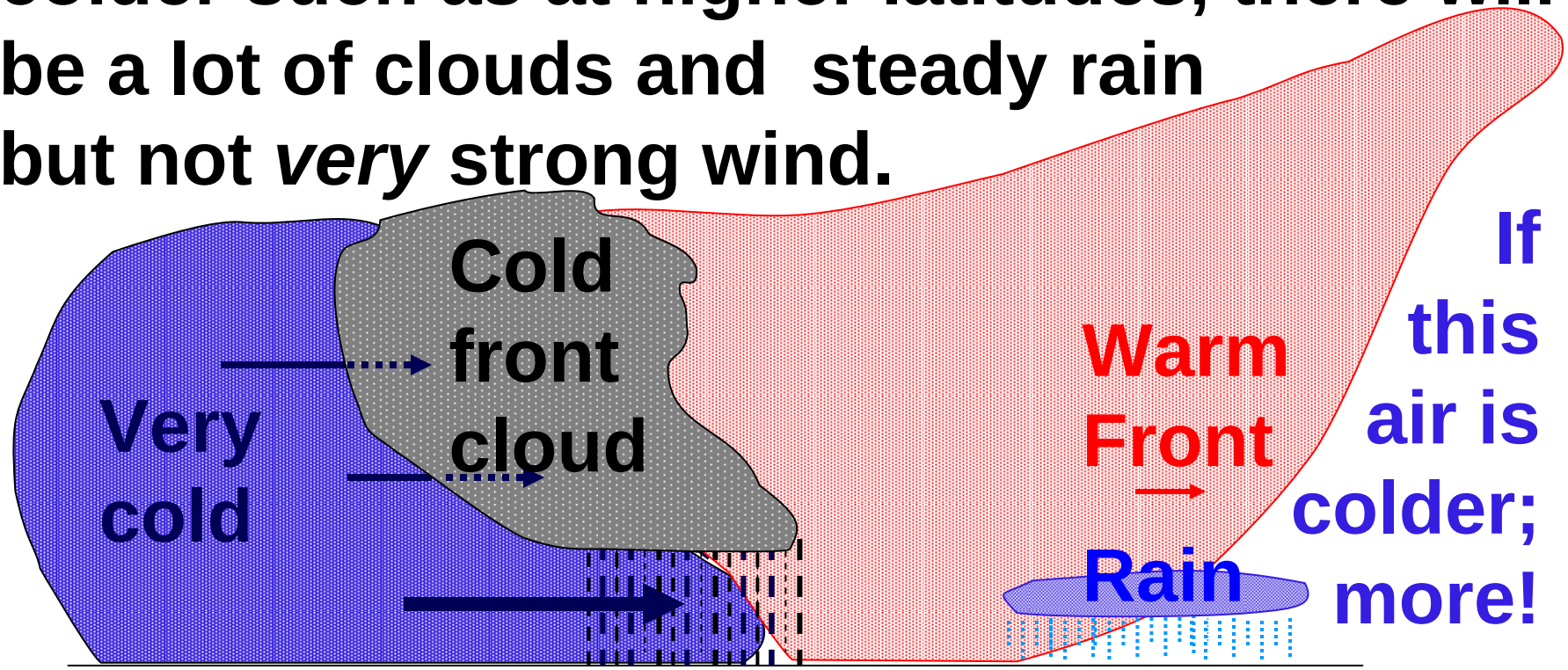
If the air ahead of the ‘front’ of the warm air is cold, then there WILL be some dark condensation (clouds), coalescence, and then precipitation. So it depends on the temperature of the air ahead of the warm air; cool = not much condensation,

cold = more dark clouds and rain.

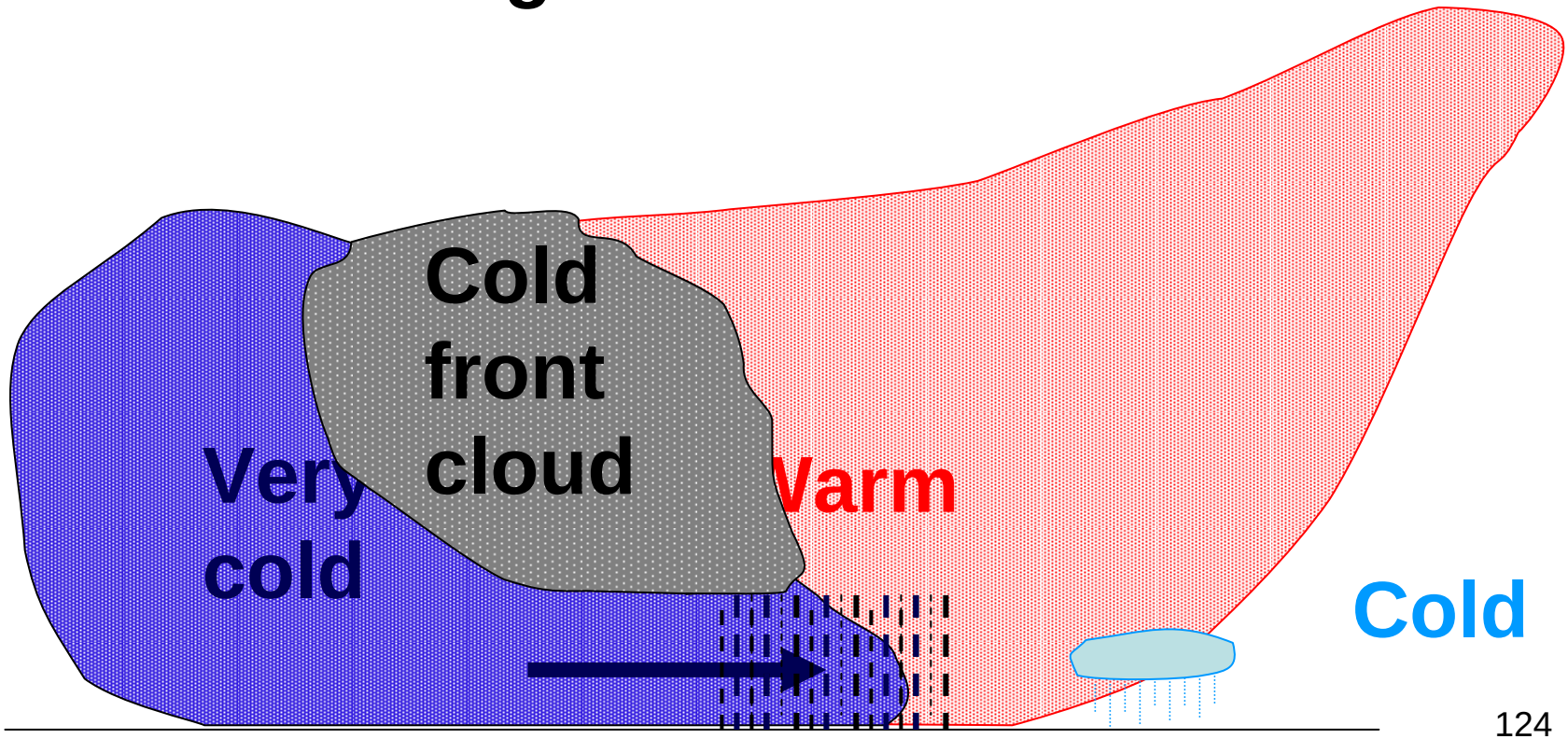
Northern Hemisphere Southern



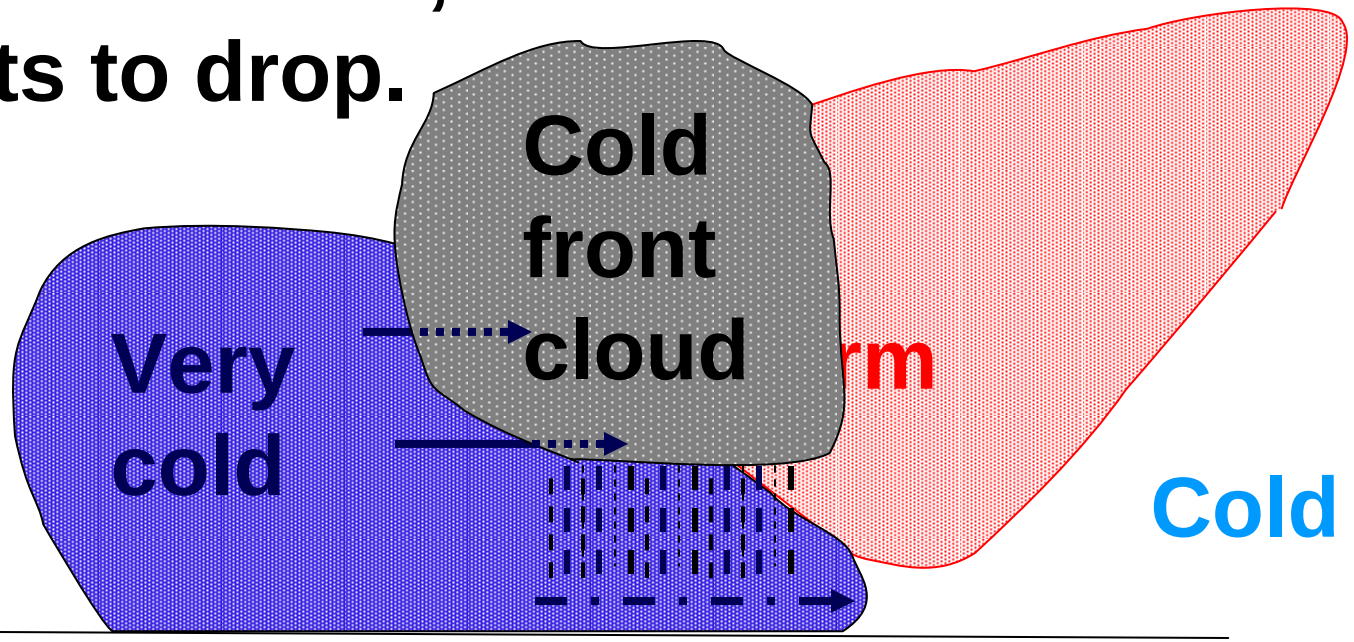
So, as we know when the air ahead of the approaching 'Warm Front' is not cold, but just cool or even warm, there will be little if any rain and also clouds, but when it is a lot colder such as at higher latitudes, there will be a lot of clouds and steady rain but not *very* strong wind.



As time goes on, the warm air and its humidity is ‘eaten up’. The faster moving very cold air is advancing in on the decreasing volume of warm air.



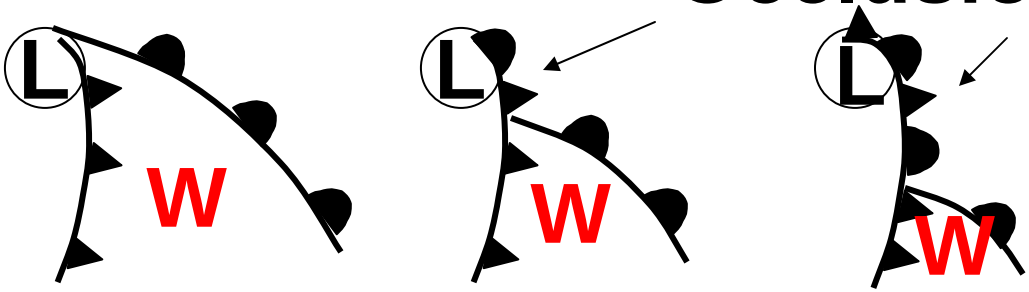
Then “Occlusion” occurs – the very cold air has pushed in under the warm air, the lower part of which is seen to rise. So at sea level there is no Very Cold against Warm air – the rain rises and decreases, and the sea wind starts to drop.



When seen on Synoptic Charts (weather maps) note the symbols for Cold Fronts and Warm Fronts; see where Occlusion may have started to occur – the front is fading.

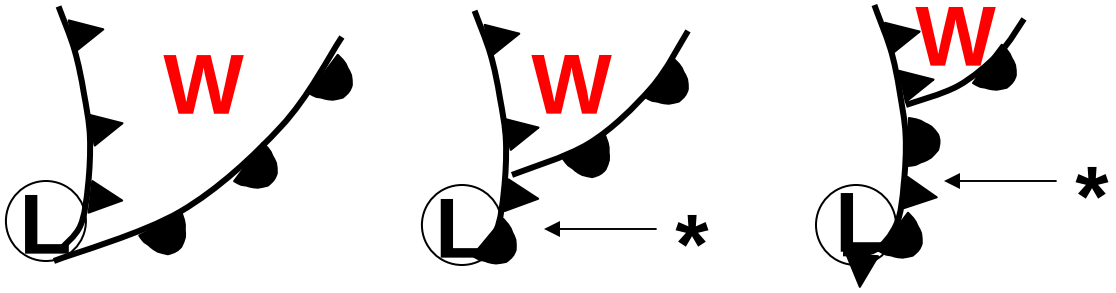
Occlusion*

Northern Hemisphere

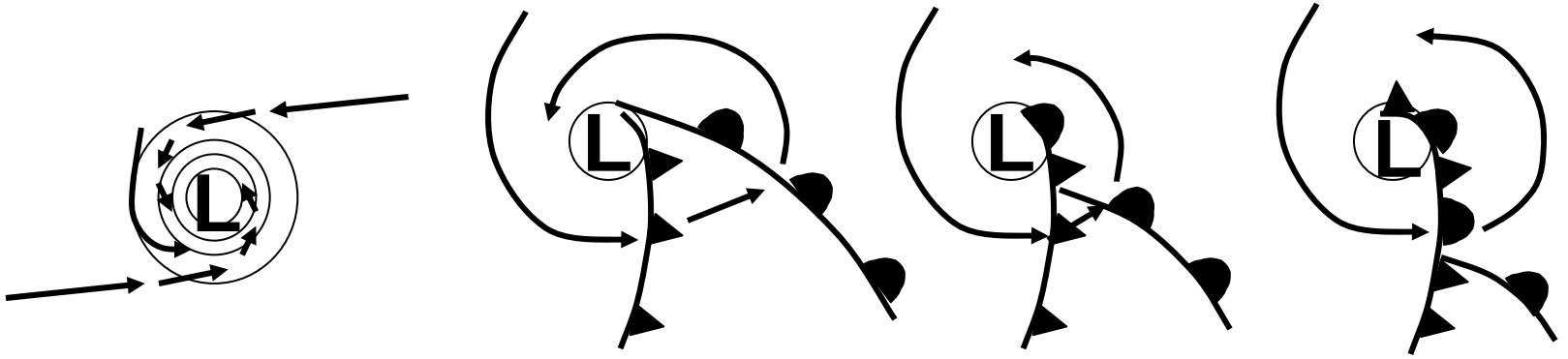


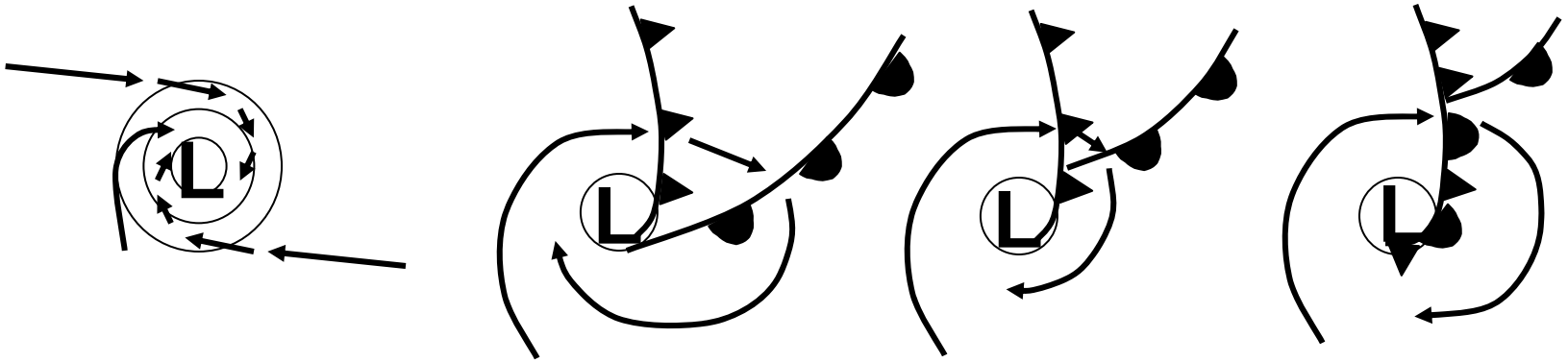
Started **Later** **Ending**

Southern Hemisphere

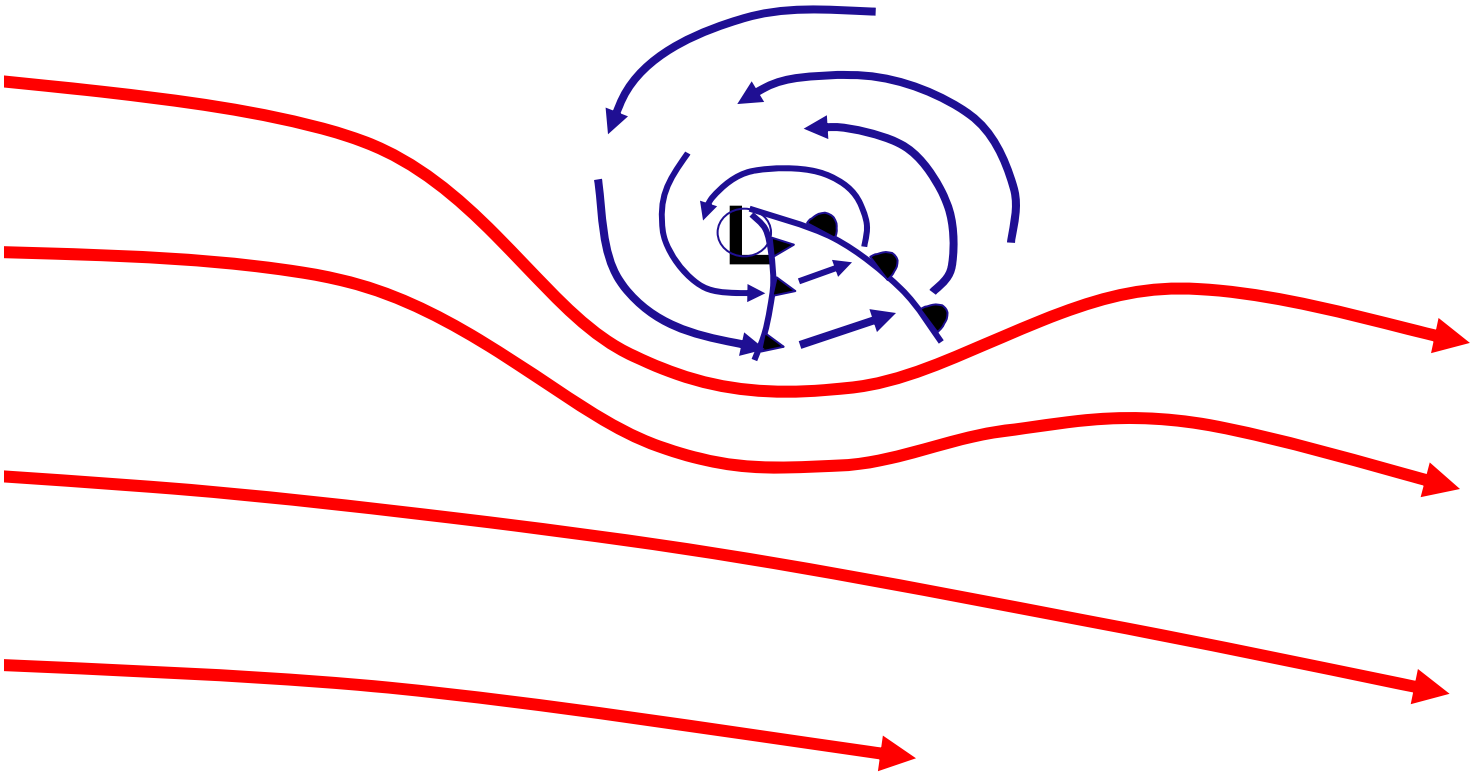


Wind ‘spiraling’ into the Low changes directions at a Cold (and Warm) Front:

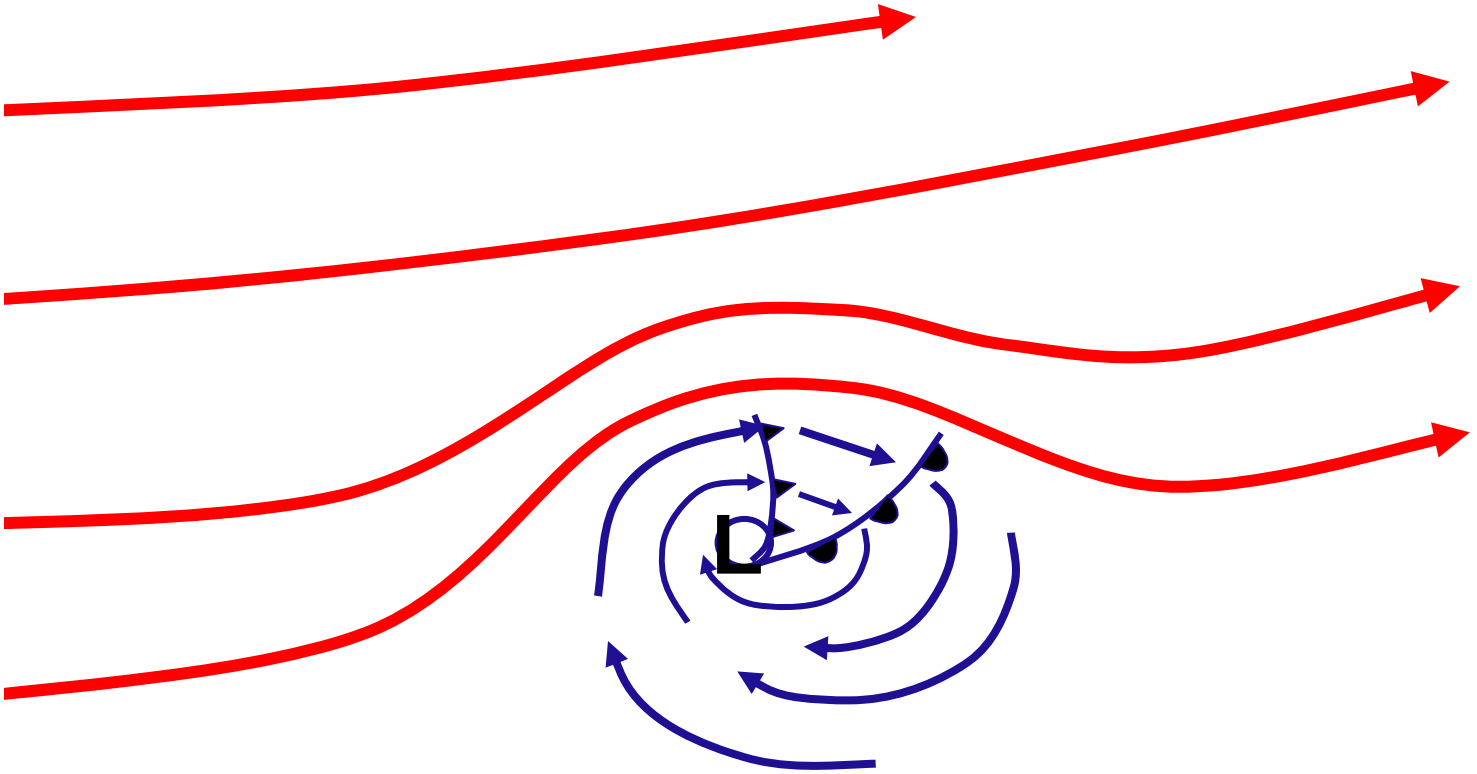




In the Northern Hemisphere we see the wind directions around the ocean High near a cold front, and around the Low as:



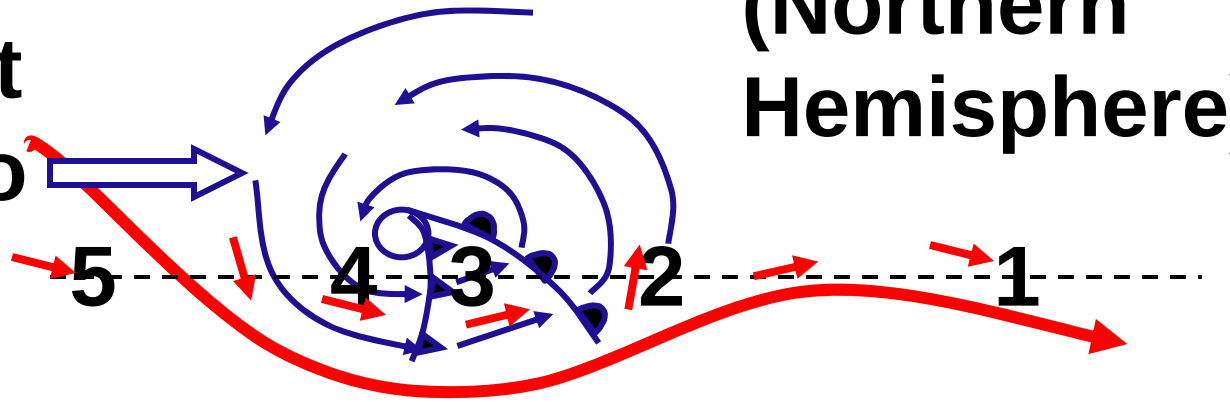
In the Southern Hemisphere we see the wind directions are only different because they curve in the opposite directions.



See what to expect of wind direction changes as a front approaches and passes:

(Northern Hemisphere)

The front moves to the east

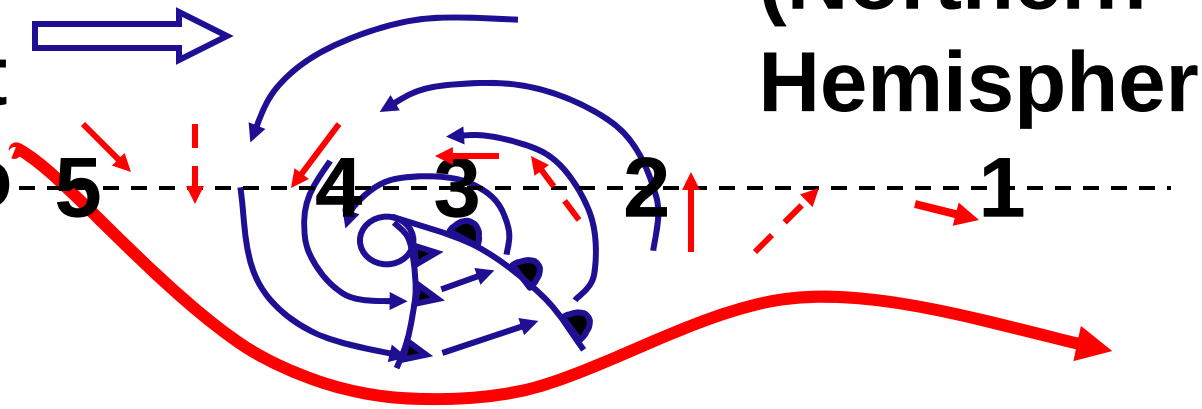


1. Before it arrives our wind is West of North West – WNW. 2. As it arrives the wind changed anti-clockwise, it BACKS. 3. Then it moves a little clockwise, it has VEERED. 4. Veered more. 5. Normal again.

If it approaches and passes south of you, i.e. on the equator side of you:

(Northern Hemisphere)

The front moves to the east



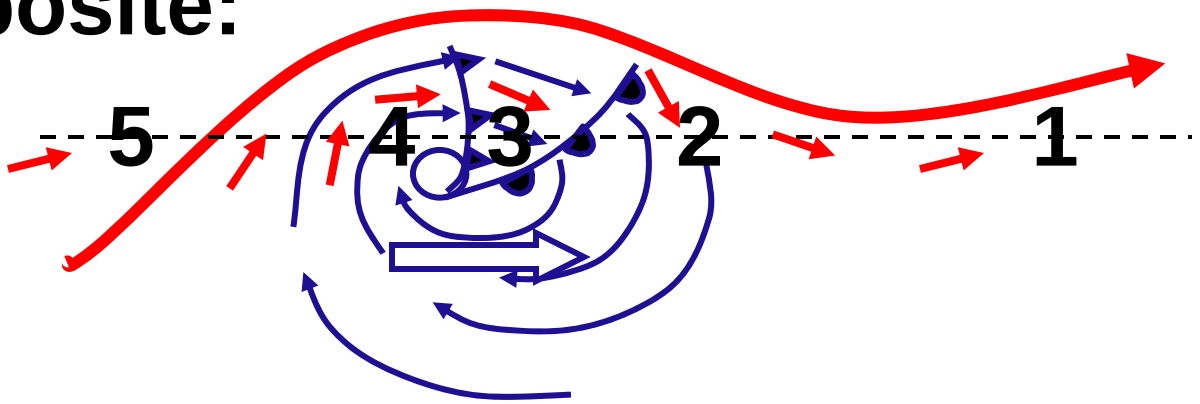
1. Before it arrives our wind is West of North West – WNW. 2. As it arrives the wind changed anti-clockwise, it BACKS. 3. And Backs. 4. And Backs. 5. And Backs back to normal again.

“Veer/s/ed” means the wind direction has changed in a clockwise direction. As an example, wind from the north changes to being ‘from’ north east, then from east.

“Back/s/ed” means the opposite direction of wind change, e.g. wind from the north becomes ‘from’ north west, then west.

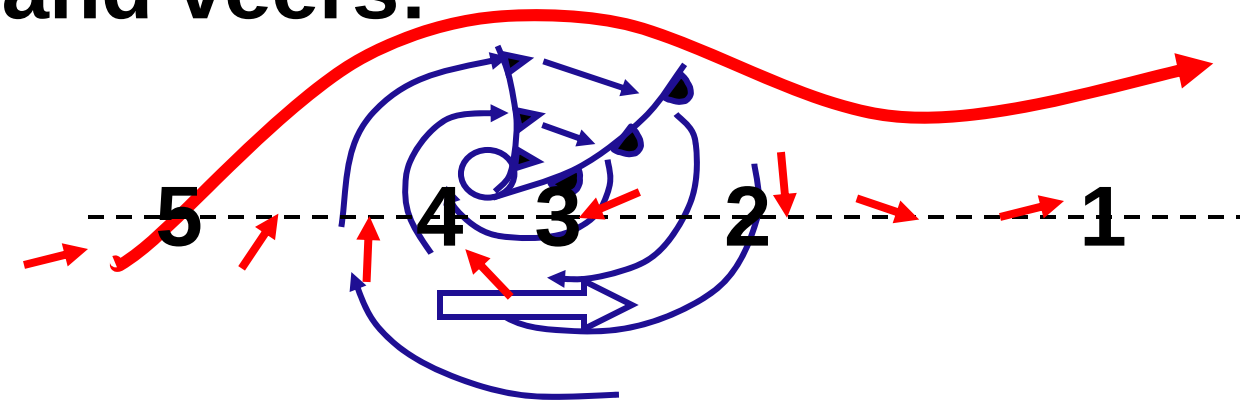
In the 21 century, these terms apply the same in both hemispheres, but there are officials who still use the old method where they mean opposite directions i.e. BACK in the south = VEER in the north.

In the Southern Hemisphere it is exactly the same but a mirror image – directions are opposite:



1. Before it arrives our wind may be West of South West – WSW. 2. As it arrives the wind changes clockwise, it VEERS. 3. Then it moves a little anti-clockwise, it BACKS. 4. It BACKS more. 5. It VEERS to WSW.

If it passes north of you, i.e. on the equator side of your position, wind just veers and veers:



1. Before it arrives our wind may be West of South West – WSW. 2. As it arrives the wind changes clockwise, it VEERS. 3. Then it moves a little more clockwise, it VEERS. 4. It VEERS even more. 5. It VEERS to the original WSW. It has turned +/- 360°!

Why do we need to know this?

Weather forecasts are not always received when well out to sea. Never-the- less we can know a Low with or without a cold front is approaching our area.

We see the Barometer Pressure dropping!

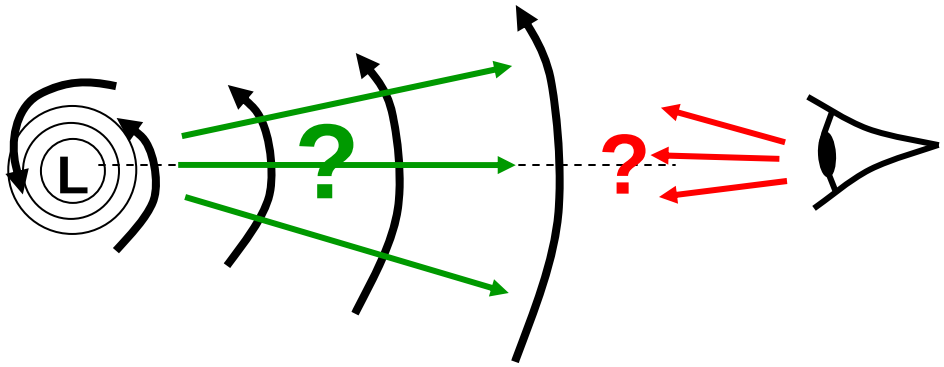
When below 1013 mb we are in the Low.

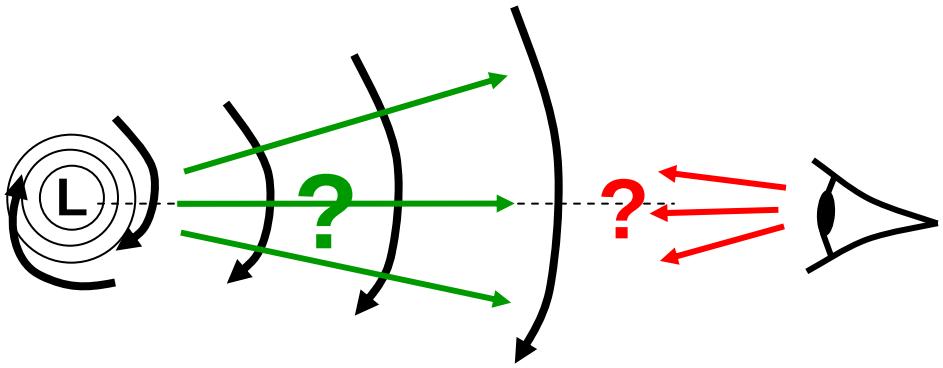
Where is its centre? Which way is it going? Do we need to change out course?

How do we know if a Cold Front is coming?

Where is it, its centre?

We use **"Buys Ballot's Law"** – it tells us how to determine **where the Low is,** and then how to determine whether **it will come straight at us or pass us on which side**.





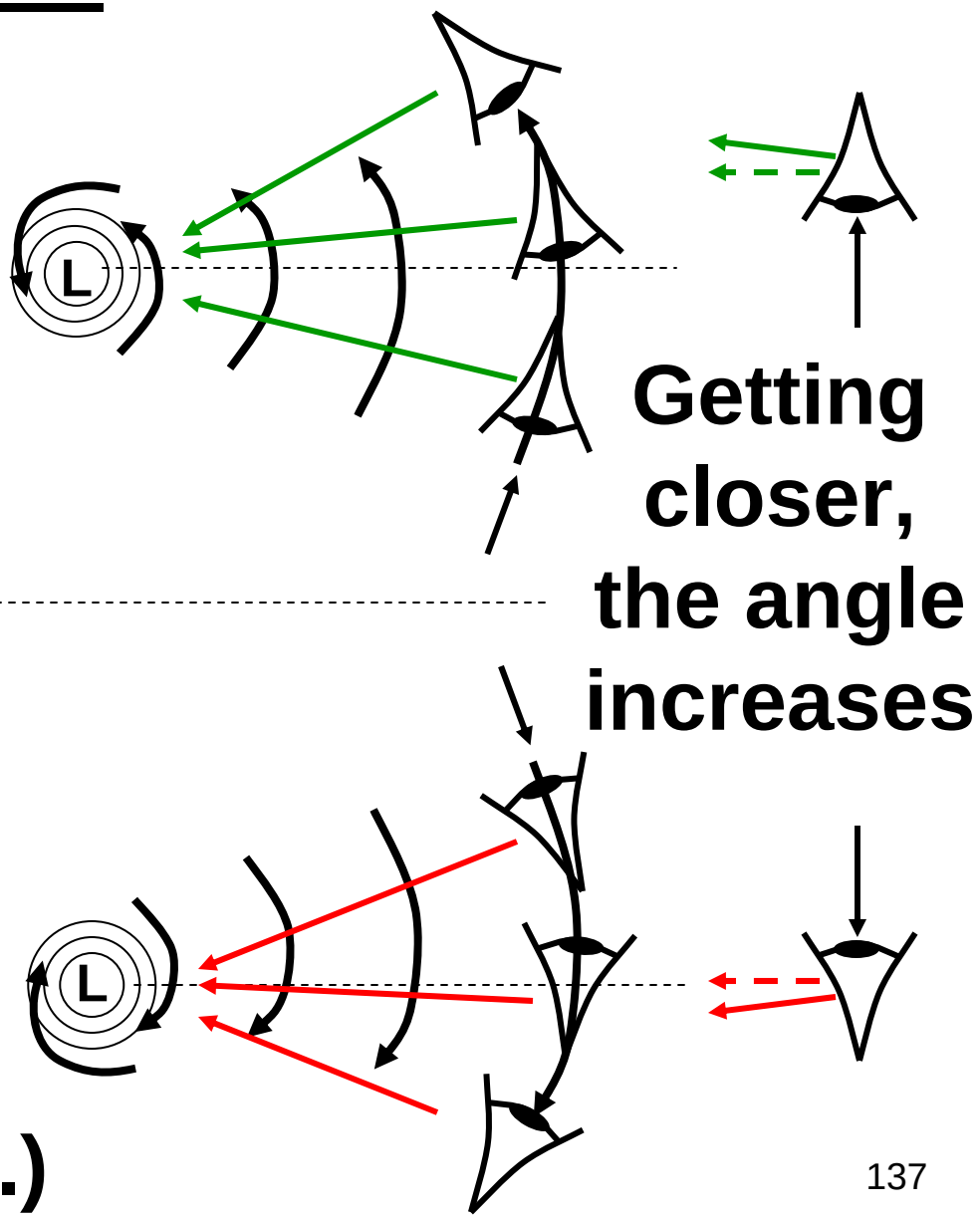
Where is it, its centre?

When approaching, *face into the wind.**

North Hemisphere:
It is over my right shoulder.

South Hemisphere:
It is over my left shoulder.

***RYA says get it on your back … (P.T.O.)**



Getting closer, the angle increases

The RYA says put your back into the wind. If you do that then what is over your left shoulder when looking into the wind becomes over your right shoulder, etc.

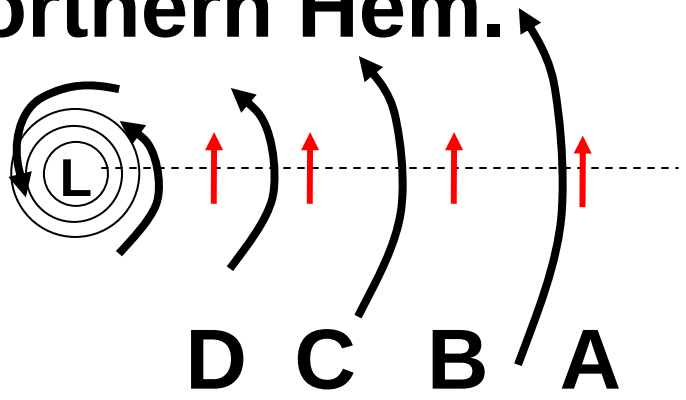
An advantage may be that you do not have heavy wind and breaking waves spray into your eyes. But how accurate will you be?

I believe that will only happen when the Low is already getting very close. Having your eyes and face's cheeks into the wind gives a much more accurate determination of wind direction, and therefore the Low.

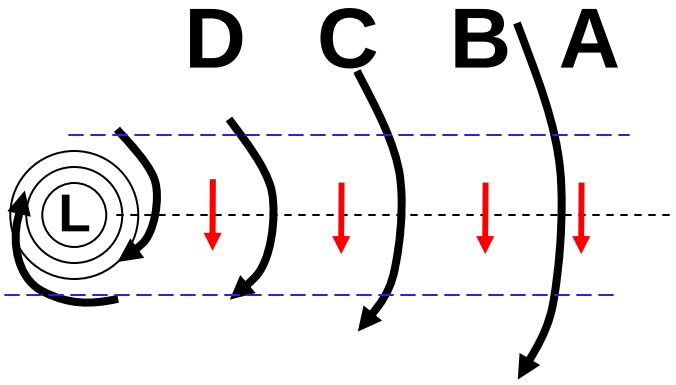
Is it coming straight at us?

If you see the wind direction is <u>not</u> changing, you are on its path; it is coming straight to you.

Northern Hem.



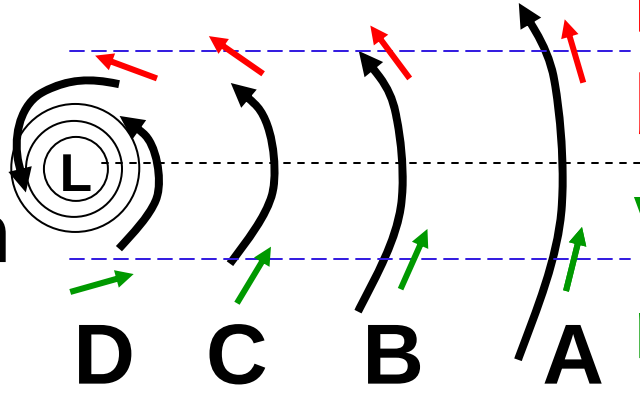
Southern Hem.



If at A, then B, then C, then D and the wind stays the same direction, *watch out!*

Which way (direction) is it going?

If we see the wind direction is changing, the direction it changes tells us where it will pass us – north or south of us.

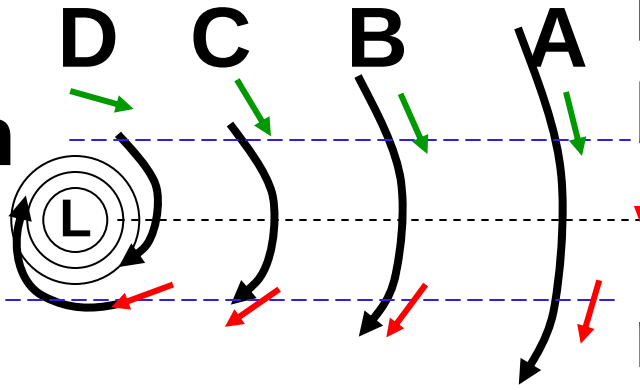


Backs, it will be south of us.

Veers, will be north of us.

Northern Hemisphere

Southern Hemisphere

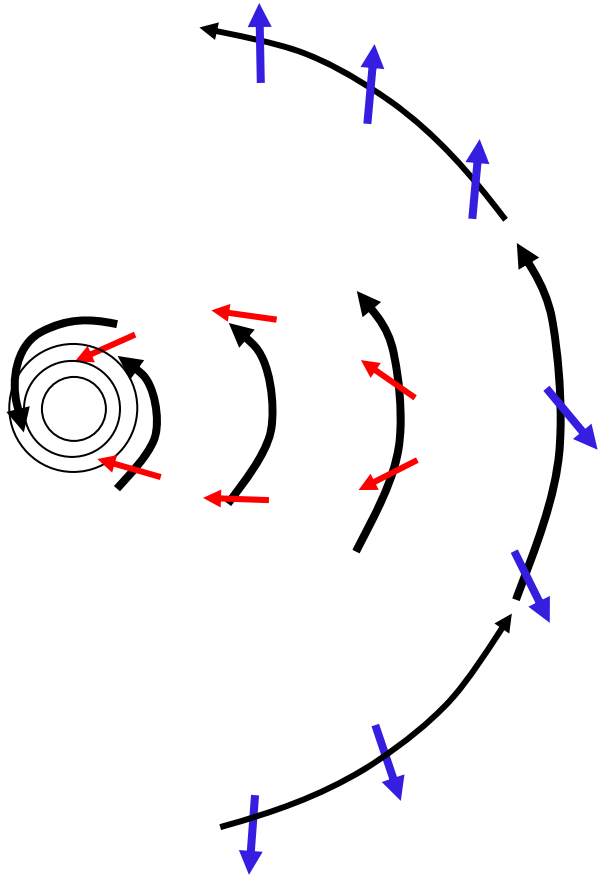


Backs, it will be south of us.

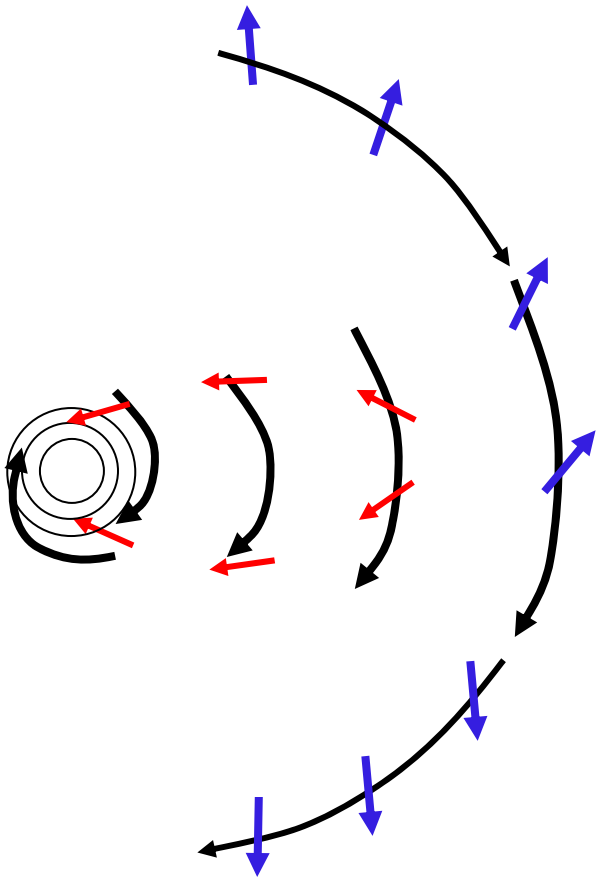
Veers, will be north of us.

Do we need to change course?

In the northern hemisphere we need to have the wind on the starboard side of the vessel, power or sail. If it is on the port side it means we are going closer to the centre of the Low, the centre of a storm?



In the Southern Hemisphere, the wind should be on the port side of the vessel to ensure movement is away from the centre of the Low where wind is strongest. If the wind is on the starboard side it will result in the vessel going into the centre of the Low.

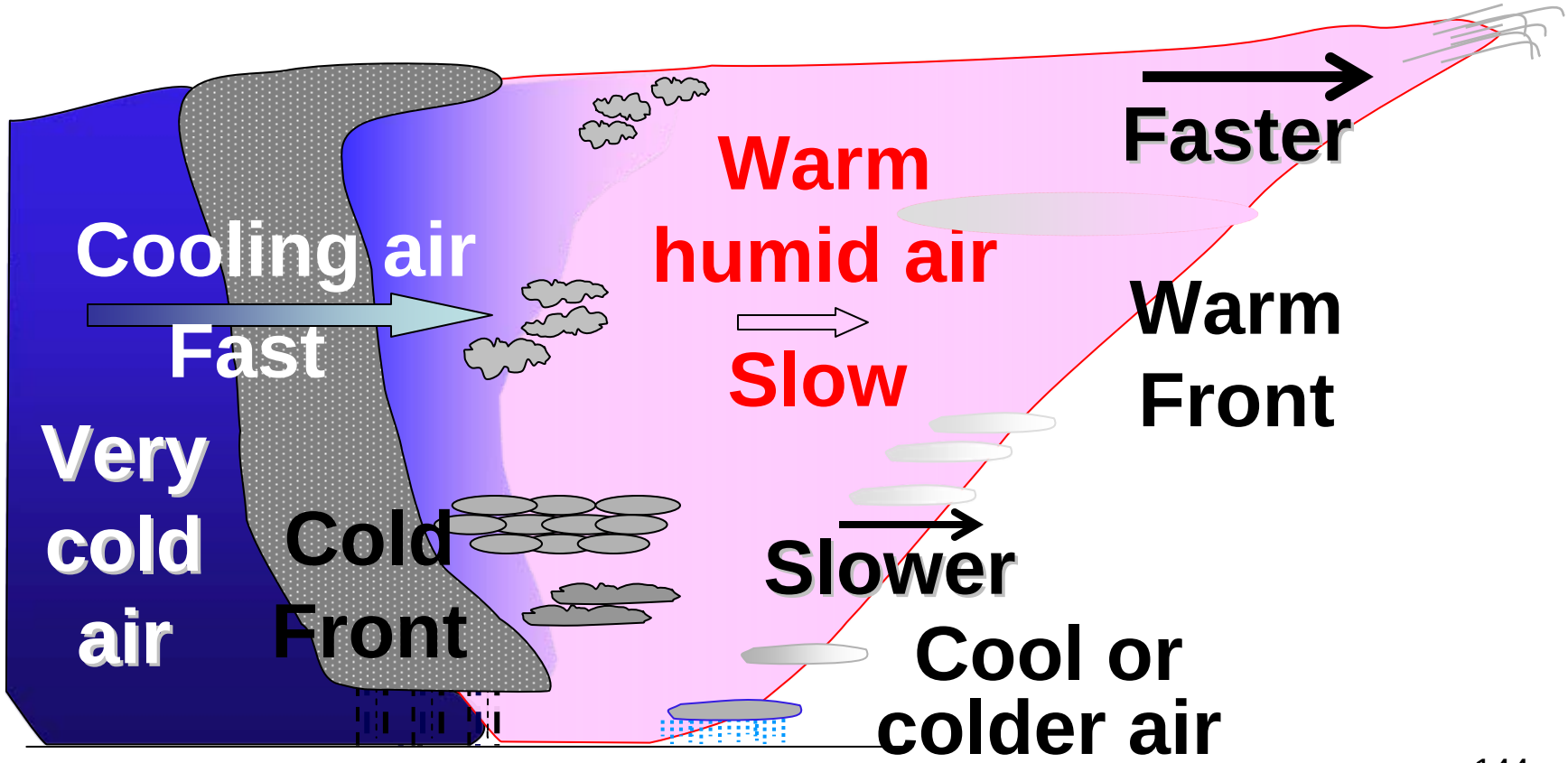


How do we know if a Cold Front is coming?

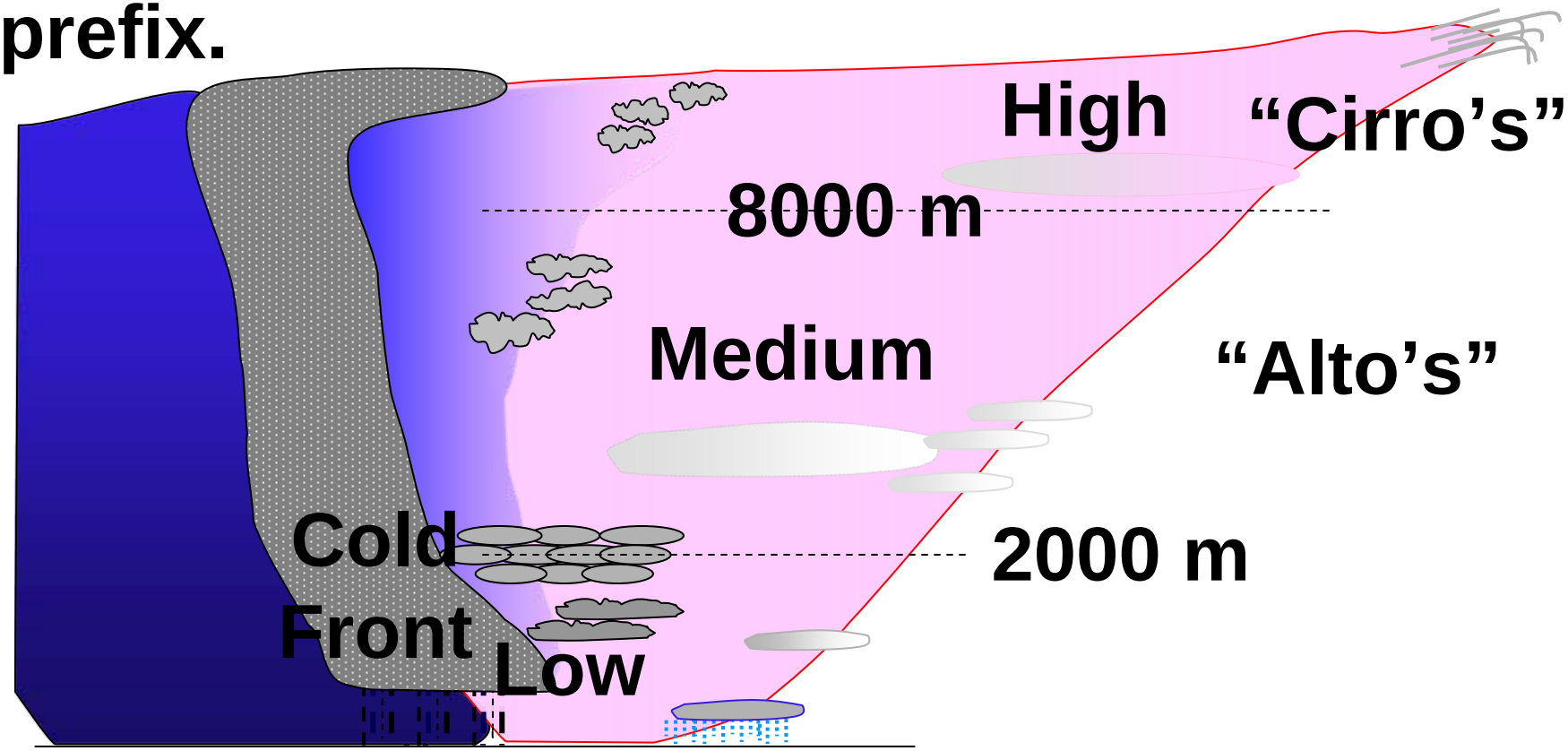
We know that when warm humid air is cooled below the "Dew Point", i.e. when 100% humidity continues to cool, then condensation occurs. Clouds are seen ...

At the leading edge of the warm air we see cooling from the air ahead. As the cool air is not very cold, the speed of condensation is slow – there is only little wind; these clouds are relatively smooth, "Stratus". Cold Front, windy/rough clouds are "Cumulus":

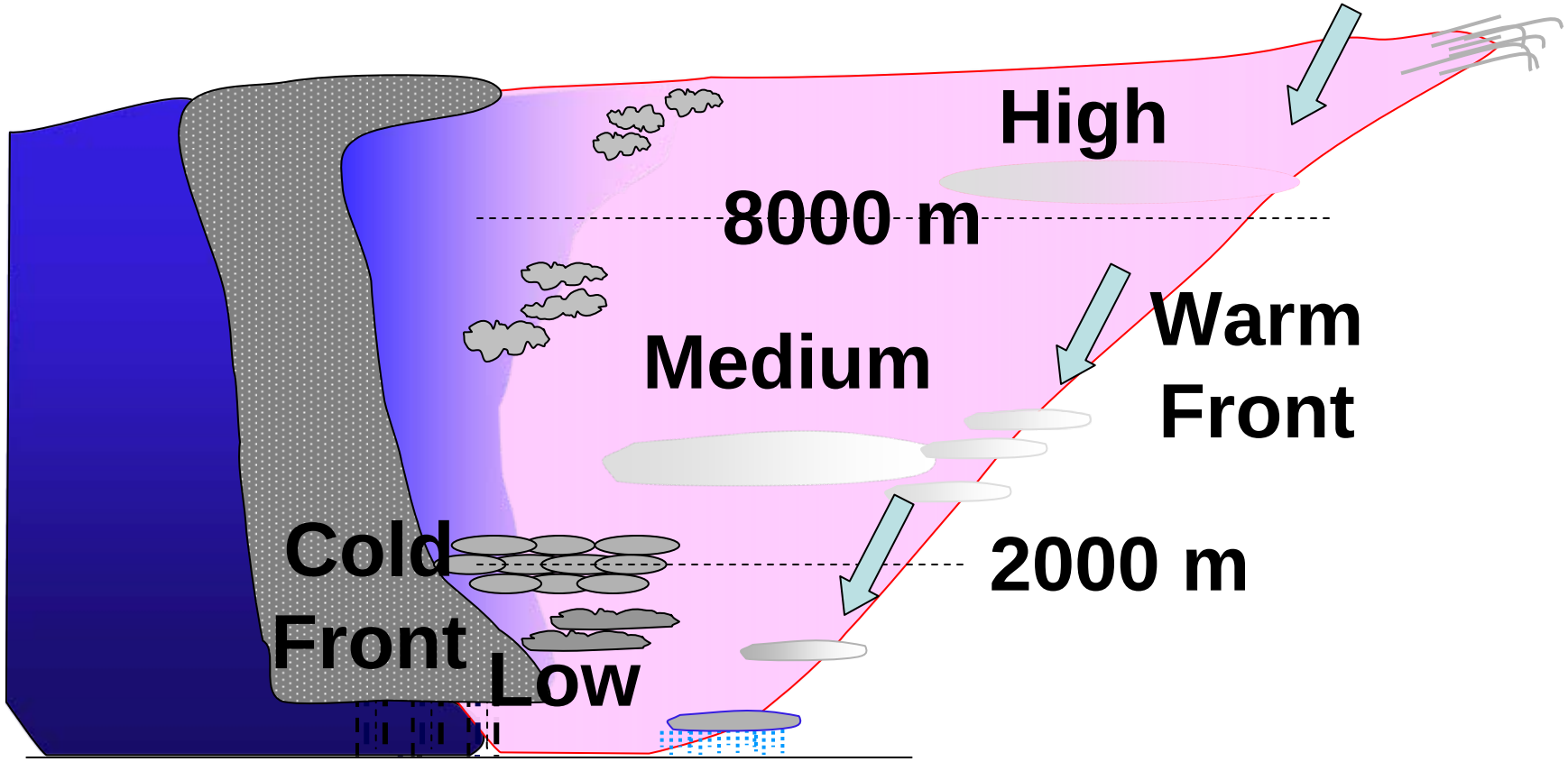
High level wind is fastest. Low level air is slowed by the slower earth rotation speed being further away from the equator. So there is a sloping edge of the Warm Front.



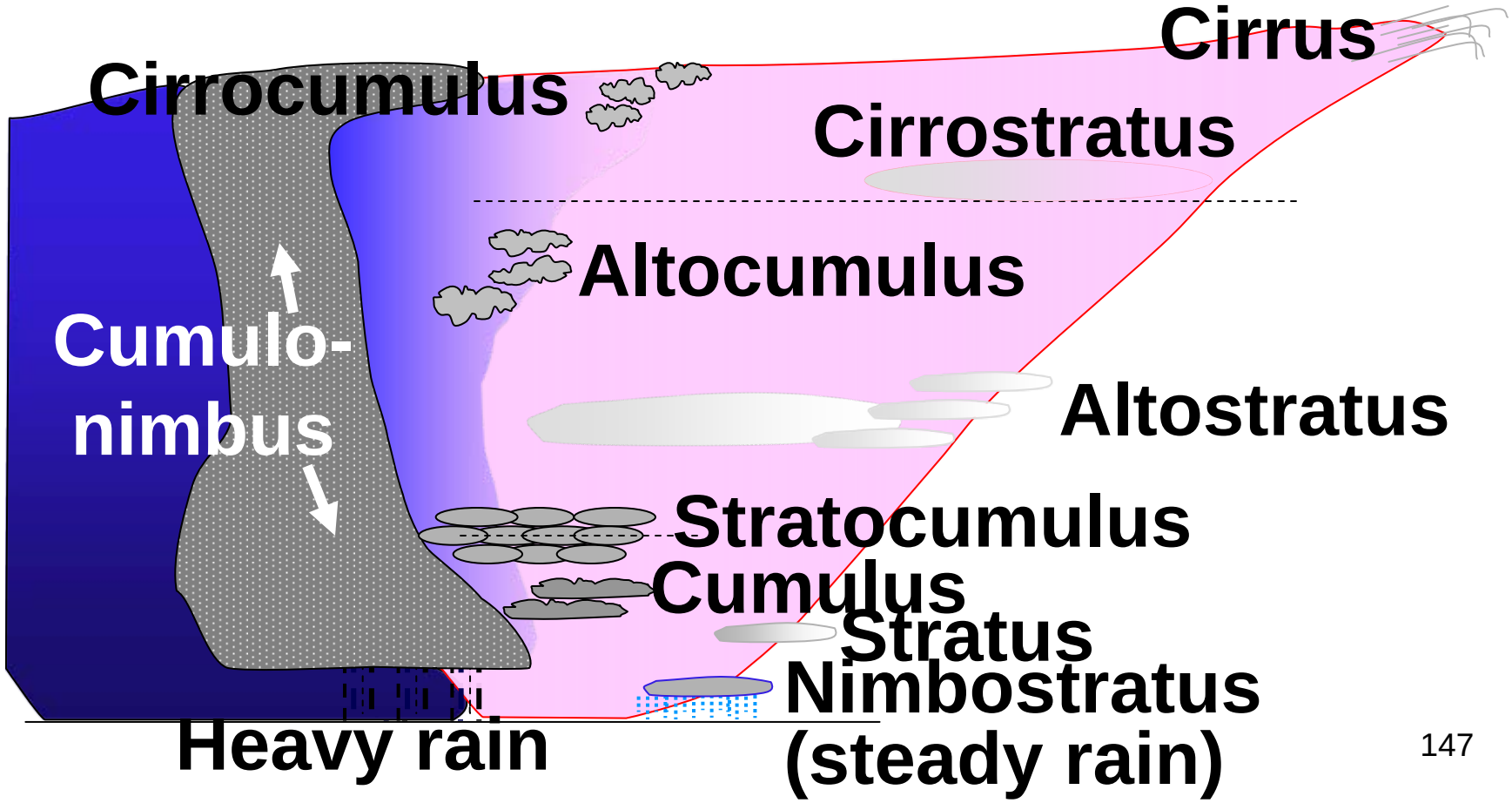
Clouds above 8000 m are the High clouds, high = cirro. Clouds between 2000 m and 8000 m are the middle level clouds, middle = “Alto”. Clouds below 2000 m have no prefix.



The leading Warm Front clouds are smooth layer "Stratus" clouds where there is a smaller air temperature difference than at the cold front, due to slow condensation.



For practical sailing purposes, names are not too important, but when first seeing the high clouds come over the horizon, then clouds getting lower, A FRONT IS COMING!



The highest Cirrus clouds – see streaks:

Cirrocumulus – high, small lumpy clouds:

Cirrostratus – high hazy clouds. See the halo around the sun when seen through it.

Other clouds seen below or above the smooth Cirro-stratus.

Altocumulus – any ‘middle level lumpy’ clouds – sometimes some types are seen in irregular sequence.

Altostratus – ‘middle level smooth and deep’ cloud – nothing visible through it .

Some other clouds seen above or below it.

Stratocumulus – a dark layer of lumpy clouds, all are joined together and no sky or anything visible through them. It will not normally be long before rain starts.

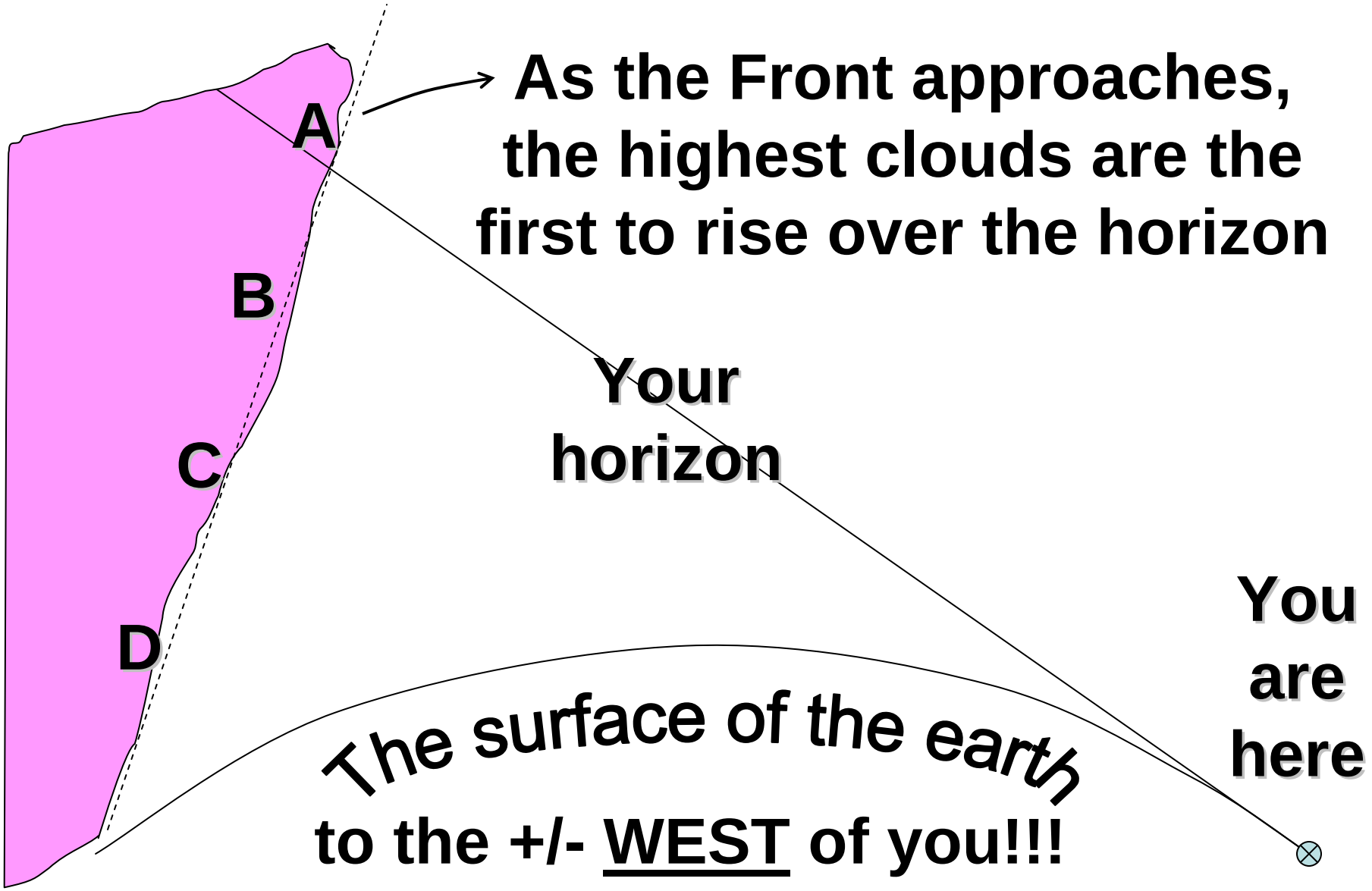
Cumulus clouds – usually with a flat dark bottom. If not part of the 'cold front' clouds sequence, it normally will be indicating nice sailing speed Trade Wind, but here the wind was lighter. We were motoring!

Stratus – mainly smooth and low clouds, with gaps between them. If at sea level, it is fog:

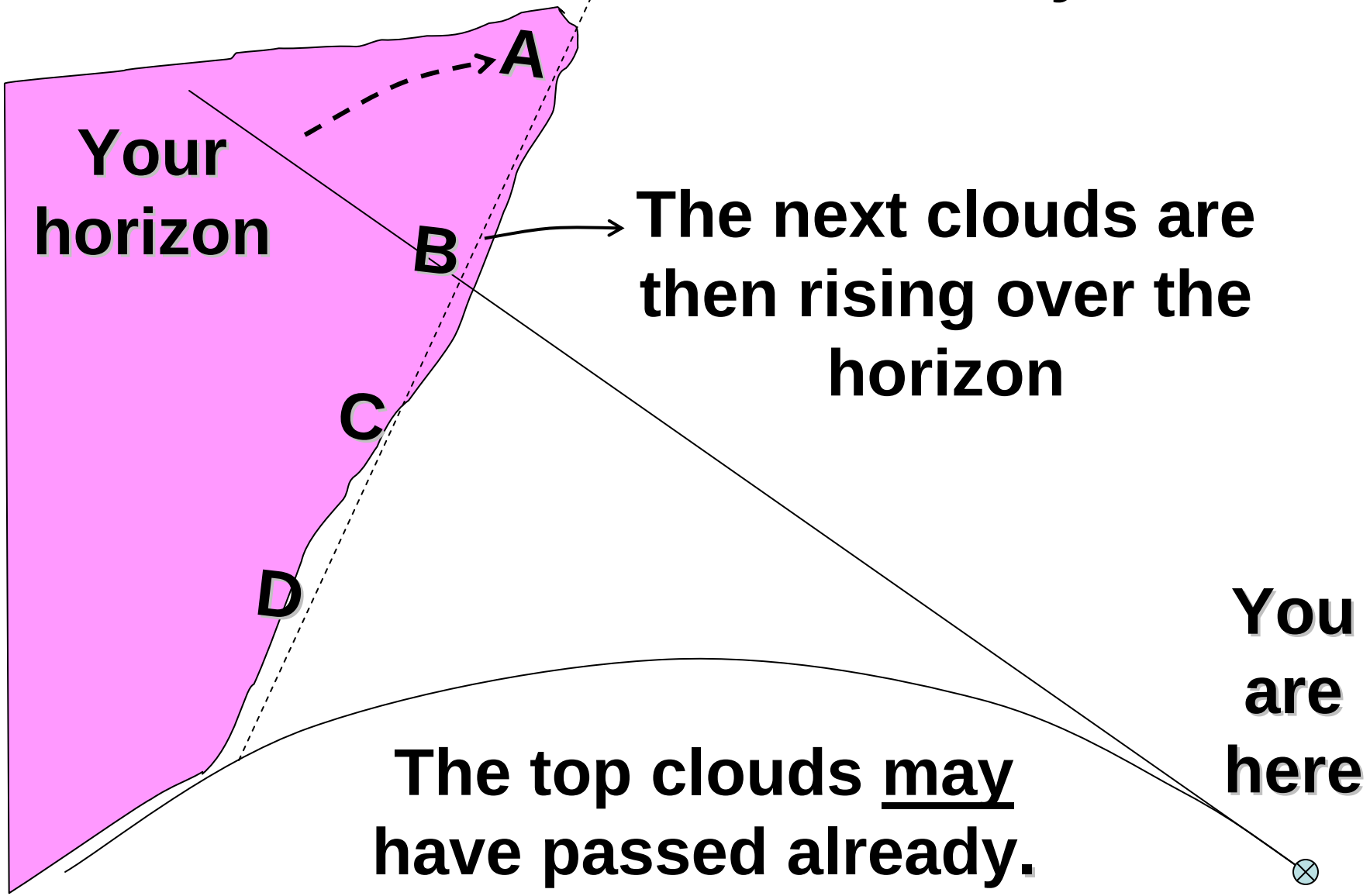
Nimbostratus – dark and rain imminent or it is raining – here it was moving from port (left) to (right) starboard. We can only see the bottom of it approaching.

Cumulonimbus – a sight very rarely seen. Rain was pouring down under the bottom dark area to the right. We only see its side.

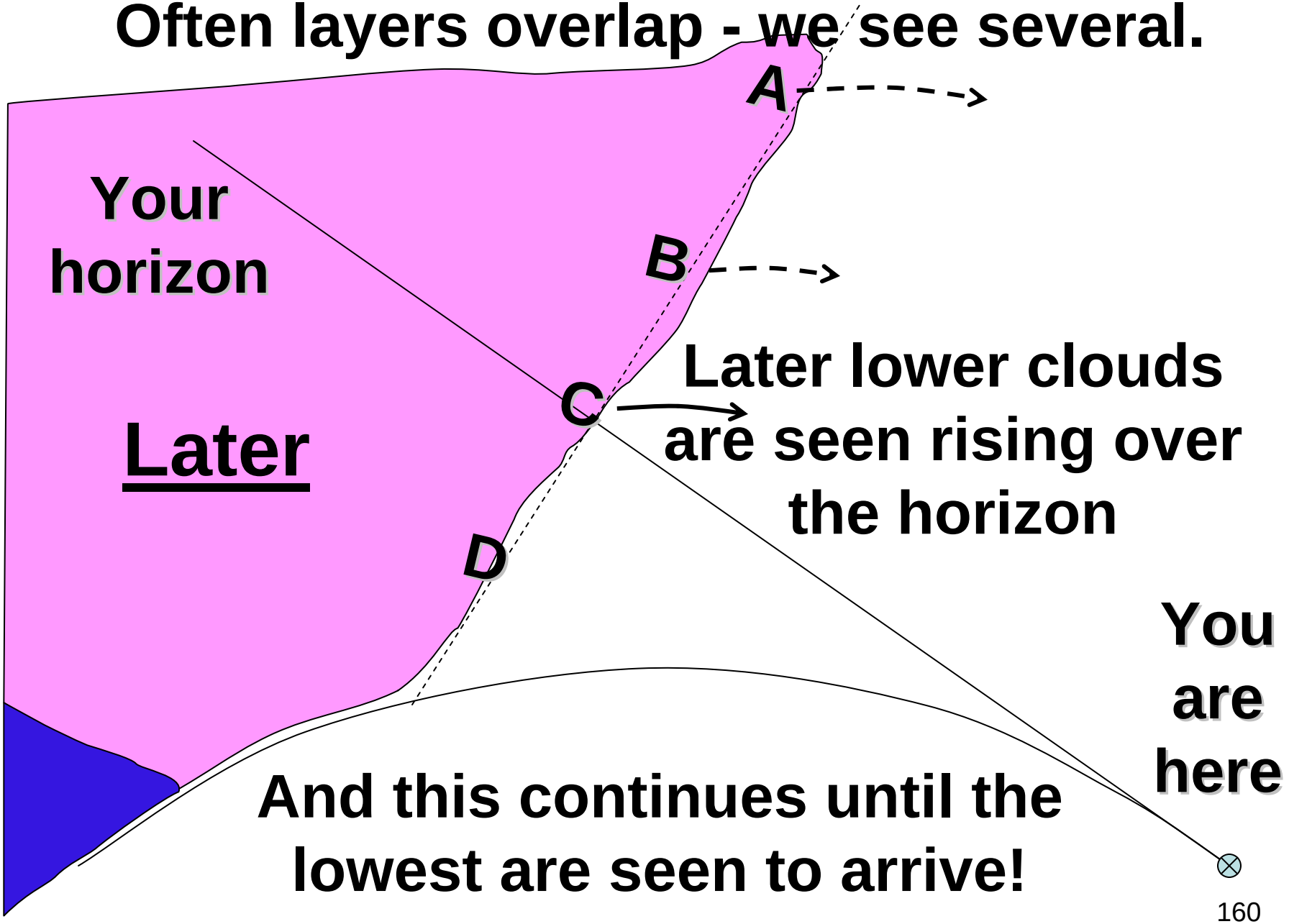
So … when we see them:



A few hours later … the next may be seen



Often layers overlap - we see several.



The cirrus clouds of a ‘front’ are *usually*(?!) about 500 n.m. ahead of the cold front. As clouds follow getting lower, the wind direction changes, as shown on pages 128 to 134.

When we see the wind direction changes, clouds down to the lower levels, and the sky gets darker, rain is not far away.

However, while observing high clouds changing as lower clouds arrive, it may happen that suddenly there is a clear sky. If it stays clear, the ‘front’ is going to pass to one side of you, not over you.

Quite often we see that the clouds moving take a long time – either they are moving slowly (maybe being blocked by a High pressure ahead) or each type is covering a long distance, and many may overlap.

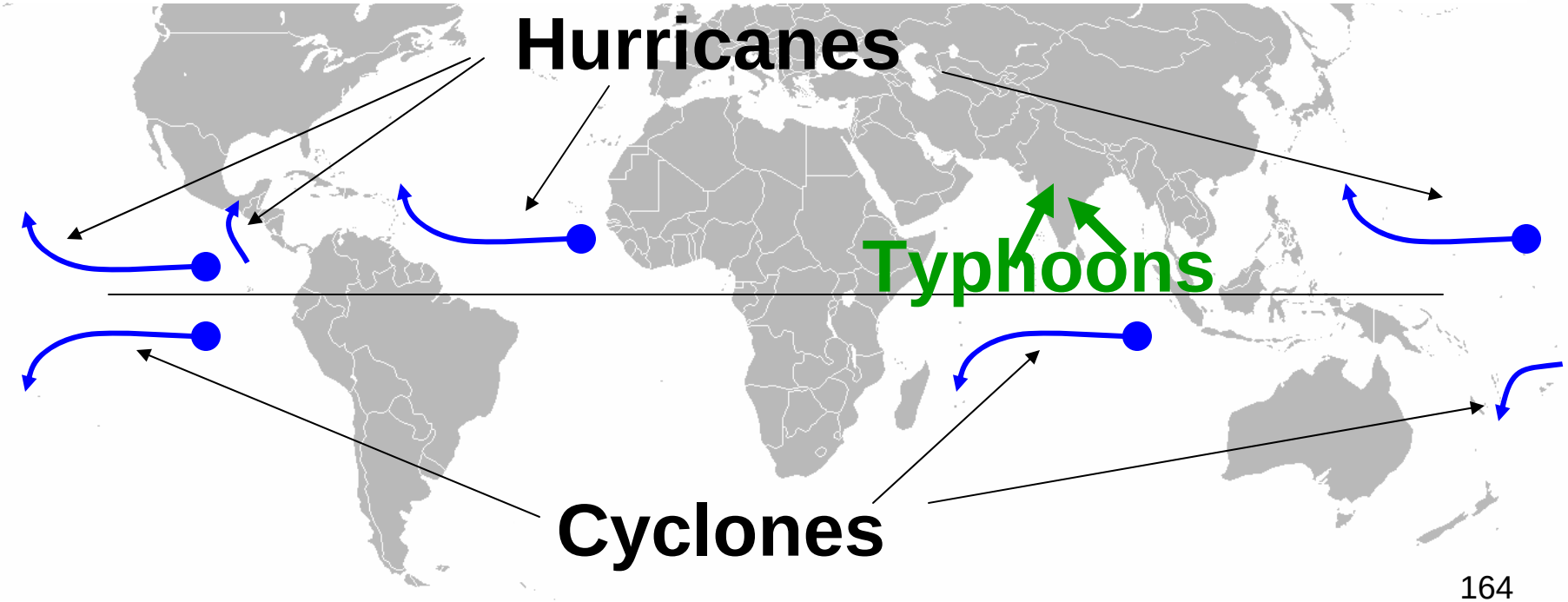
Tropical Revolving Storms, T.R.S.'s

We have all heard of "Hurricanes" and "Cyclones" and we know they are the very strong winds of storms in the tropics, hence TRS's.

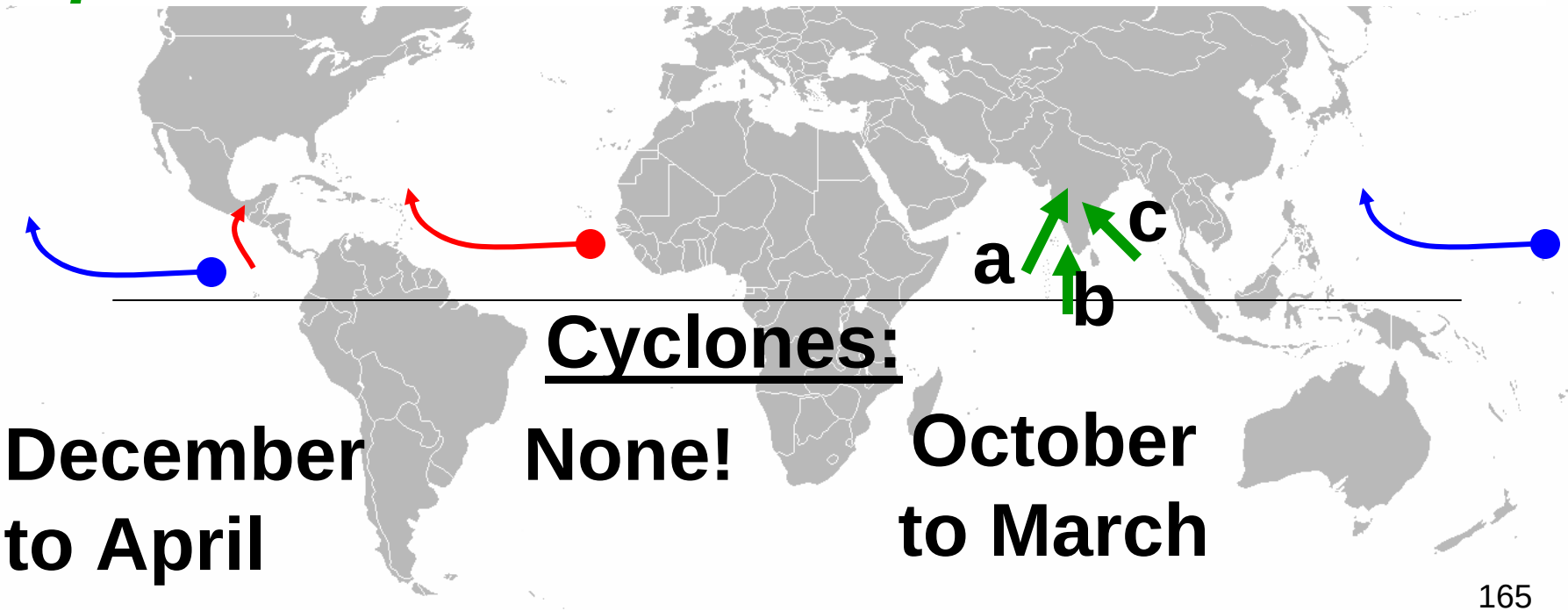
Unlike normal ocean Lows formed in the polar front and which move west to east, in the tropics we have the easterly trade winds pushing the weather form east to west.

So Lows moving east to west are to be regarded as TRS's unless proved not.

When wind speed is known to be over 54+ knots, it is termed a Tropical Depression. When it increases to over 64 knots it is a Tropical Storm, a Hurricane, a Cyclone, or a Typhoon. These occur here:

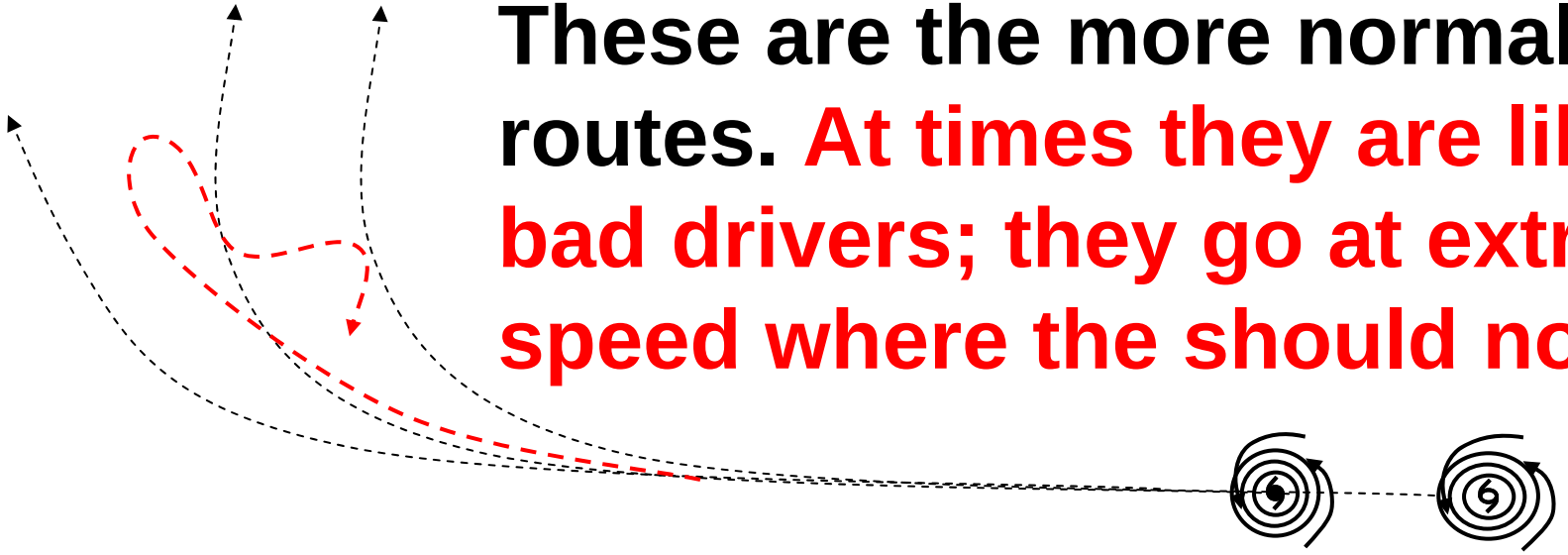


In the west of the North Pacific ocean they happen at any time. In the North Atlantic and east of the Pacific they are from June to December. Typhoons a, b, and c are April to July, September to January, and … ***April to December!!!***

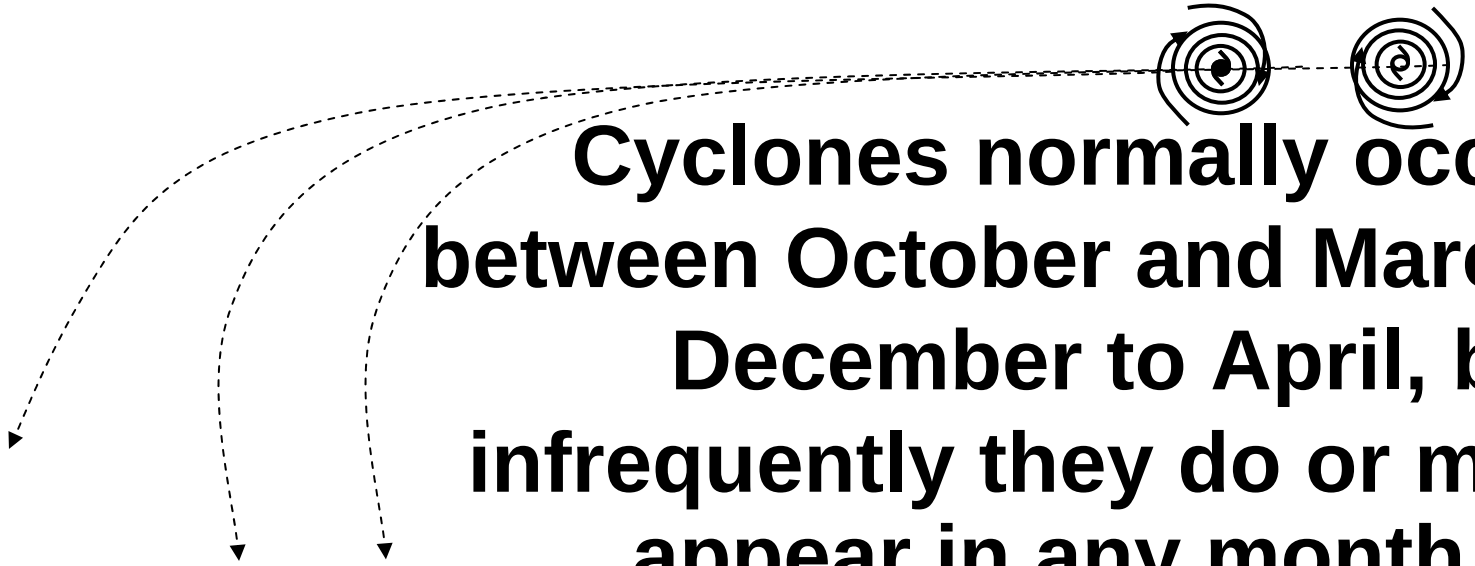


When seen on a synoptic chart, the inner symbols instead of an 'L' for Low is ♄ for Tropical Depression; when it is upgraded it becomes ♑. So we see they appear as:

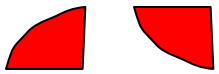
They usually form at latitudes of about 10° plus, and in the eastern half of the ocean, then follow a general direction similar to the outer winds of the ocean high pressures. When curving up to latitudes of around 35° to 40°, they then die away. Sometimes the route may be over islands and into land.



These are the more normal routes. At times they are like bad drivers; they go at extra speed where the should not!



Cyclones normally occur between October and March/ December to April, but infrequently they do or may appear in any month.



- the most dangerous quadrants to be avoided

The Path

The Track

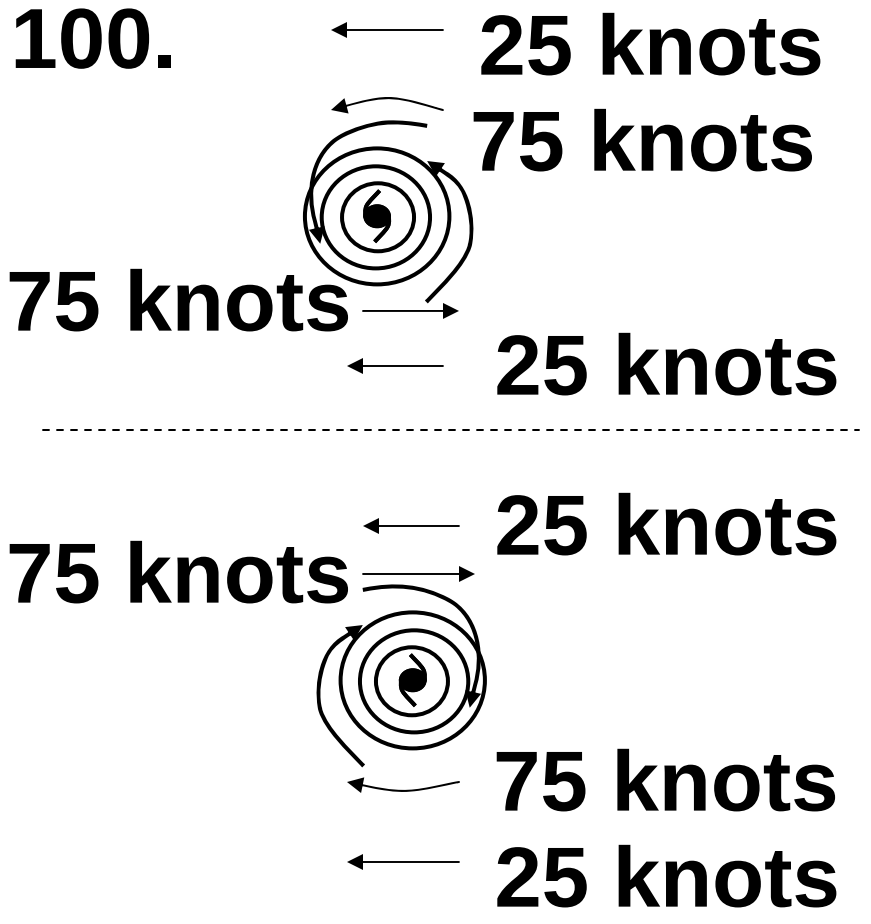
The Track

The Path

- the second most dangerous quadrants; they are to be avoided.

Imagine the wind around these TRS's are at about 75 knots. Imagine also that the TRS's are moving east to west at 25 knots - the wind on the polar side will be 75 + 25 = 100.

On the equator side it is 75 – 25 = 50 knots

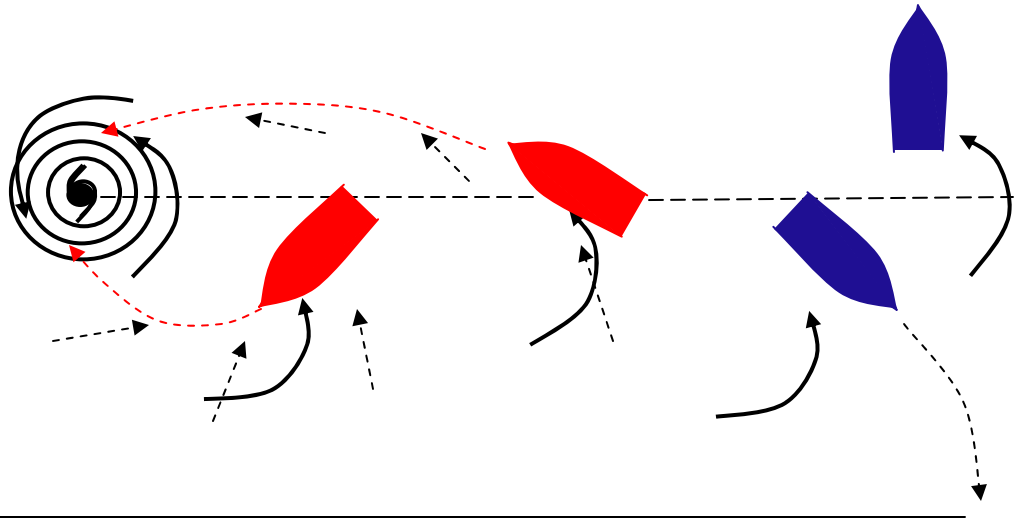


So the equator side of the path is on the opposite side to the very dangerous quadrants and the wind will be about half the speed of the most dangerous side!

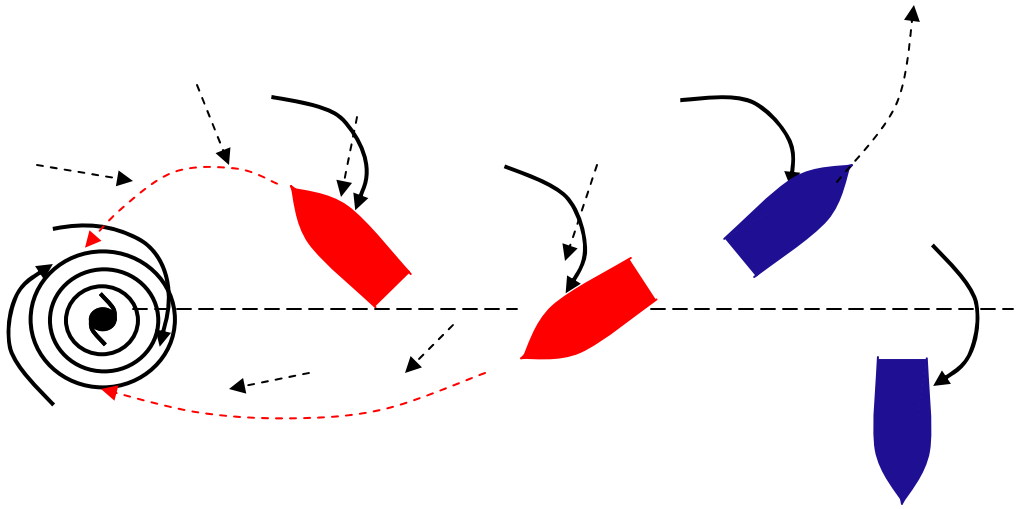
Now we also need to know, in the northern hemisphere whether on a power boat or sailing, to move away and not towards the centre of the Hurricane the wind must be coming onto the starboard side of the vessel. In the southern hemisphere the wind must be on to the port side. Let's see…

As the wind veers or backs, you want to be moving *away*, not *towards* the storm.

Northern Hemisphere - wind to be on the starboard.

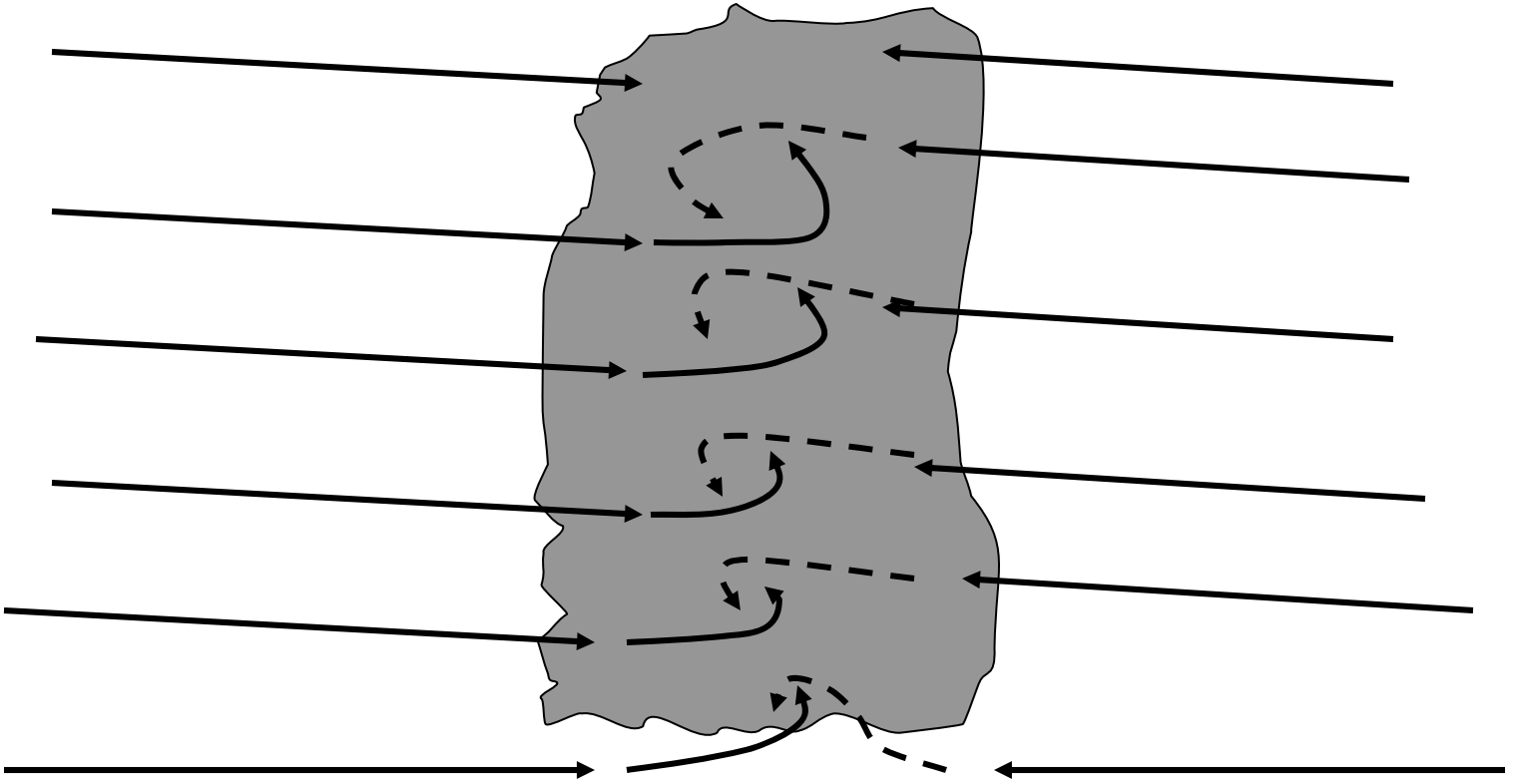


Southern Hemisphere - wind to be on the port side.

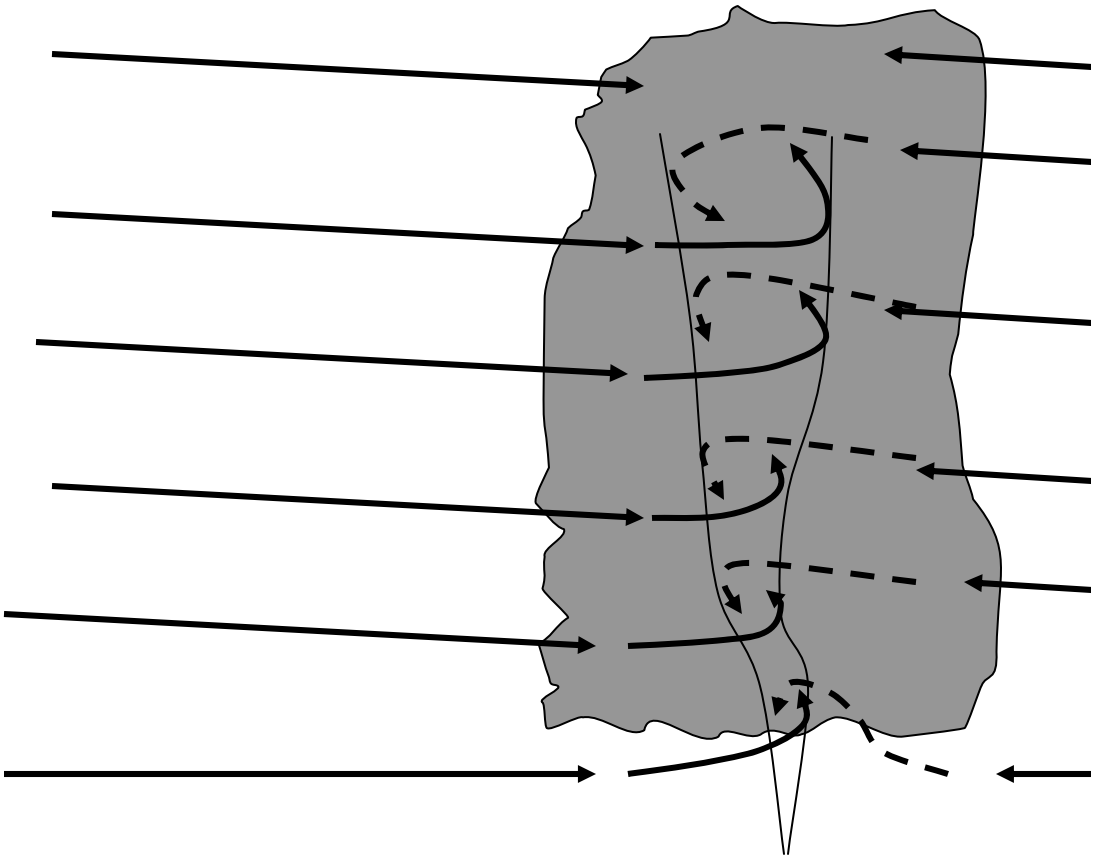


Tornadoes occur when the condensation in cumulonimbus clouds is so intense, air rushes into the cloud from all directions. High speed winds rushing together from opposite directions start to spin, re-creating a very low pressure in the cloud. As it continues and increases, it starts to spiral down – when the high speed rotating wind gets to the ground, it smashes anything and everything in its way. Objects get thrown up and away. If over water, a water spout tower occurs.

Inside a very low pressure area wind is pulled in from all sides – wind in opposite directions starts fast spinning …



When you see water starting to spin down into a basin's outlet, the top opening gets larger as the 'hole' gets deeper …



In this cloud, the spinning also starts to work down-wards. It will touch ground first as a pin! Then expand.

Low level winds can be near 200 knots!

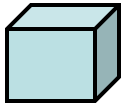
Three categories of Tornados:

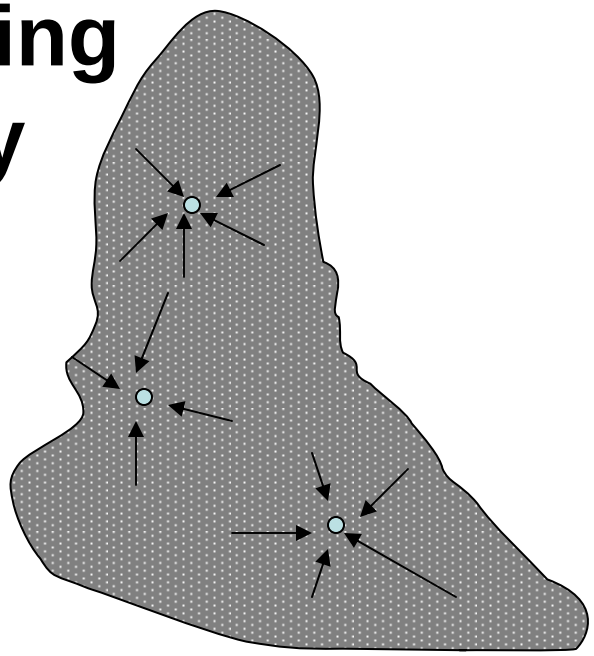
1. <u>Weak</u>, +/- 10 mins, wind up to 95 knots.

2. <u>Strong</u>, up to 30 mins, wind up to 175 knots.

3. <u>Violent</u>, +/- 1 hour, winds more than Strong.

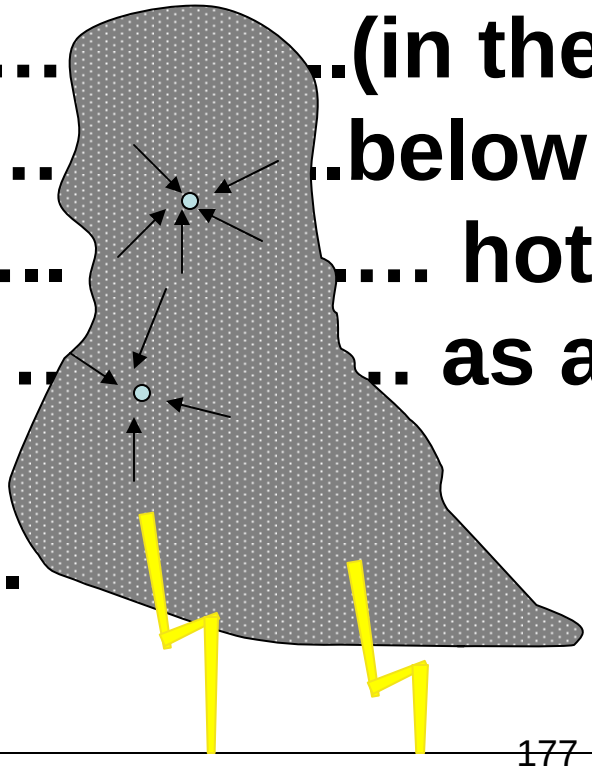
Observe the size where it touches down – about 200 m? The wind is VERY strong even miles away!

<u>Thunderstorms</u> occur in cumulonimbus clouds. The big difference in temperatures cause the warm humid air to experience rapid condensation. (Remember page 119,  **becomes ◦.) When millions of these are happening at random in varying places, air is running in many directions at any one time, then another, then another, so air turbulence becomes excessive. This results in electrical voltage build-up.**

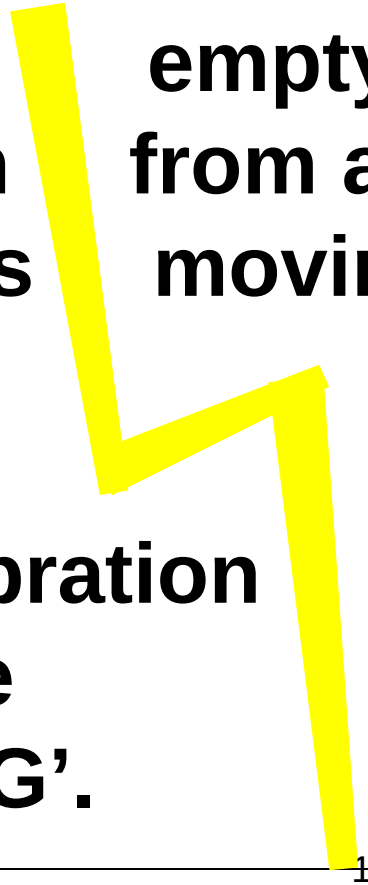


The build up of electrical charge within the cloud becomes a different voltage to the earth below, and when a relatively lower resistance path through areas of vapour condensation occurs, electric current flows from the high voltage…..(in the cloud) to the lower voltage ….below. We can see the extremely ….. …. hot electric flow burning the air …. as a very high current (amperes) discharges the high voltage.

We see this:



The lightning high current flow ‘spark’ only exists for a second, and a very short while later we hear a loud ‘bang’. All the air and vapour in its path have been burnt to nothing, leaving a ‘tube shaped’ empty gap. Air around it now rushes in from all sides to fill this gap. As the air is moving in, it is accelerating. When air from opposite directions crash into each other, the resulting vibration of the air is at sound identifiable frequencies – we hear the ‘BANG’.



The speed of sound at and near sea level and under normal conditions is 340 m/second.

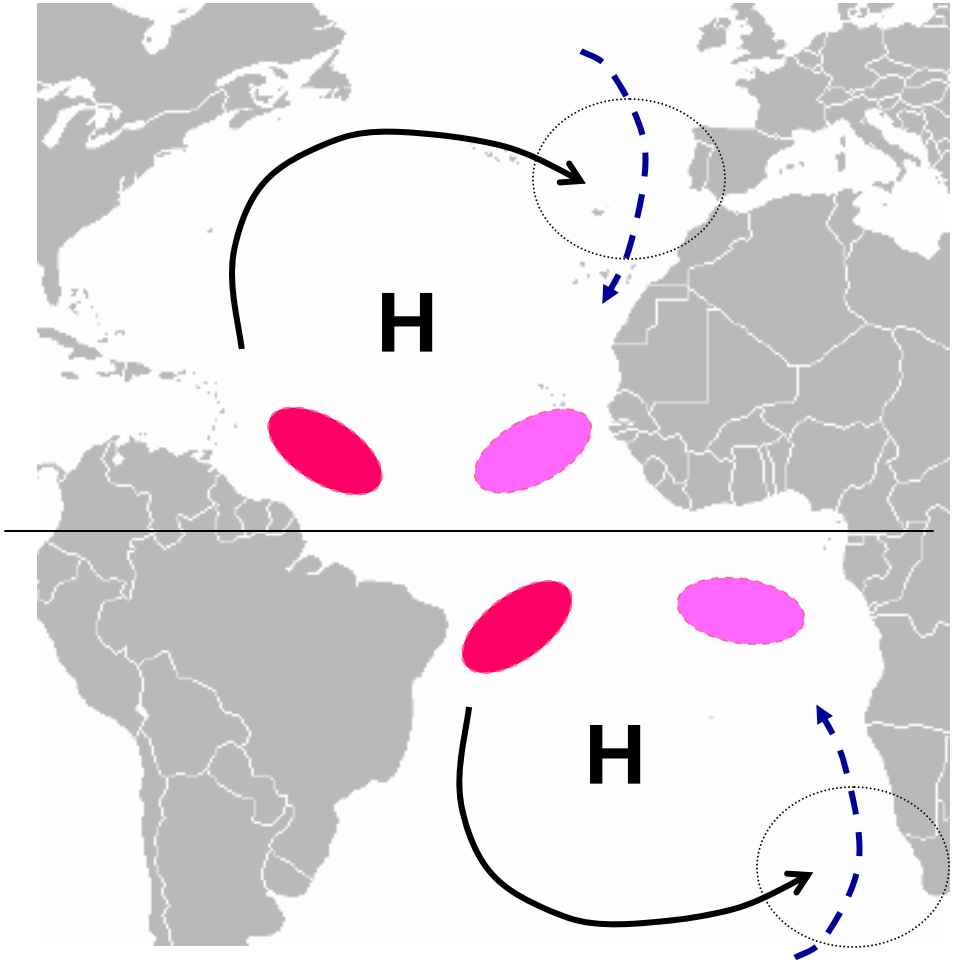
Therefore it takes:
3 seconds per kilometer,
5 seconds per mile, and
5.5 seconds per nautical mile.

So when we see the lightning, then hear the sound, we can determine how close or far away it is.

Fog - when visibility is less than 1000 m due to sea level 'cloud'. (We deal with "Advection" and "Radiation" fog.)

1. Advection fog. Whenever warm, humid air is cooled over the sea, and as a result the humidity reaches 100% or 'Due Point', any further cooling will cause condensation. The condensation that takes place appears as a cloud. If warm humid air moves over cold sea surface areas, condensation occurs at sea level – and our visibility is reduced.

Each day as the sun crosses east to west near the equator, air and sea moving the same way heats up and humidity grows!



Later, when the warm humid air circles around the High, it *may* eventually cross over cold sea where cooling and condensation may occur – it is fog.

Fog at sea is called Advection Fog – it can happen anywhere if there is cold sea and warm humid air. Once it is seen to start approaching, there are several safety actions to be applied:

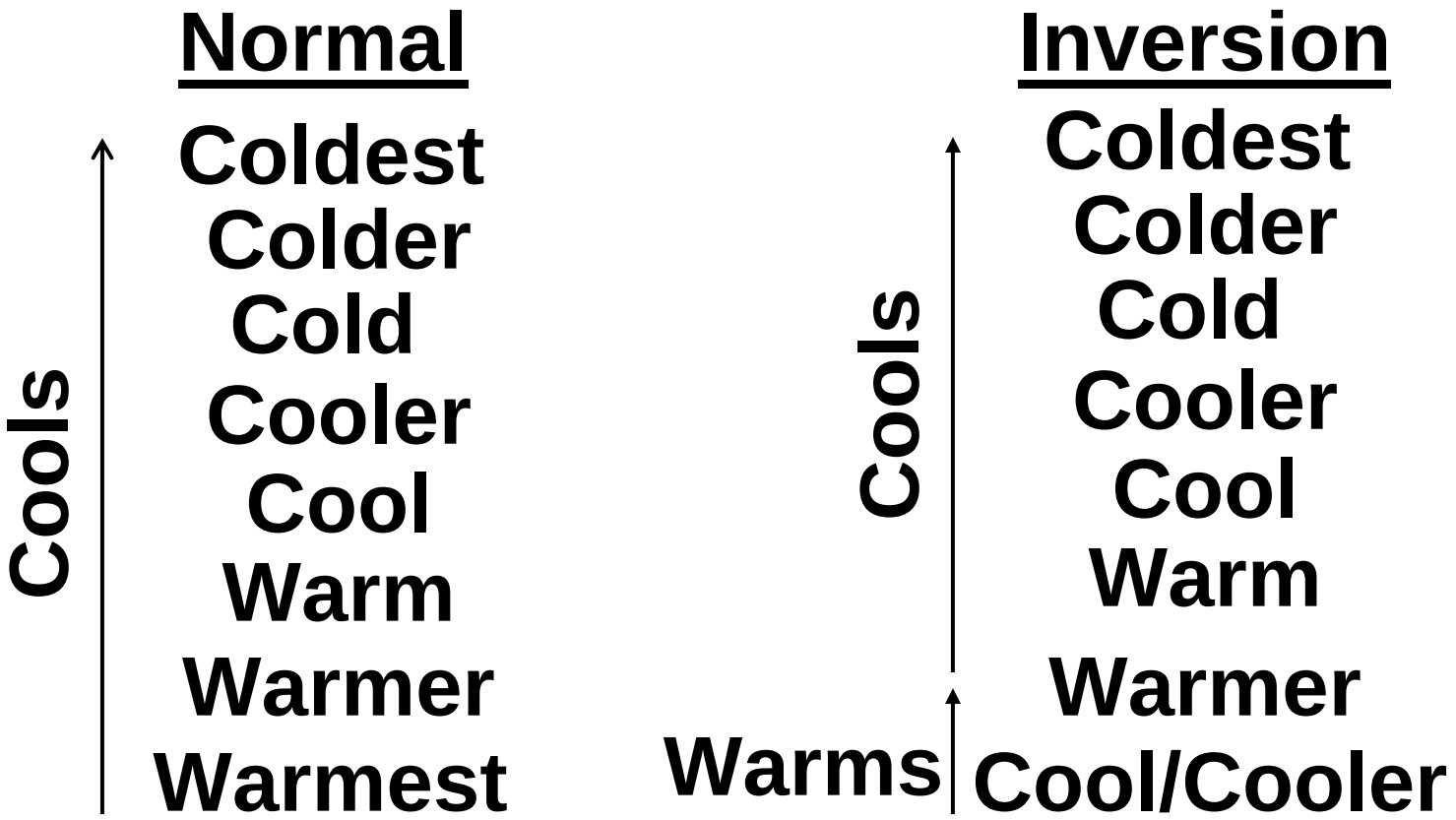
1. Slow to a safe speed. 2. Start sound signals. 3. Lights on. 4. Crew on deck with lifejackets on or nearby, and all spread around to look for other vessels or anything affecting safety. 5. Radar on, and reflector up. 6. Radio your position, course, and speed to a marine station.

“Inversion” is a result of Fog.

Normal air temperature is warmest at sea level. Air cools as height increases. Where fog occurs, the air over cold sea water cools, and therefore a warmer temperature is above the fog. From sea level fog, higher air’s temperature rises, and thereafter as it goes even higher, normal cooling then occurs.

Over fog where higher air warms, there is “Inversion” (of temperature change):

An illustration makes it easier to understand “Inversion”: Air temperature changes with height …



2. Radiation Fog

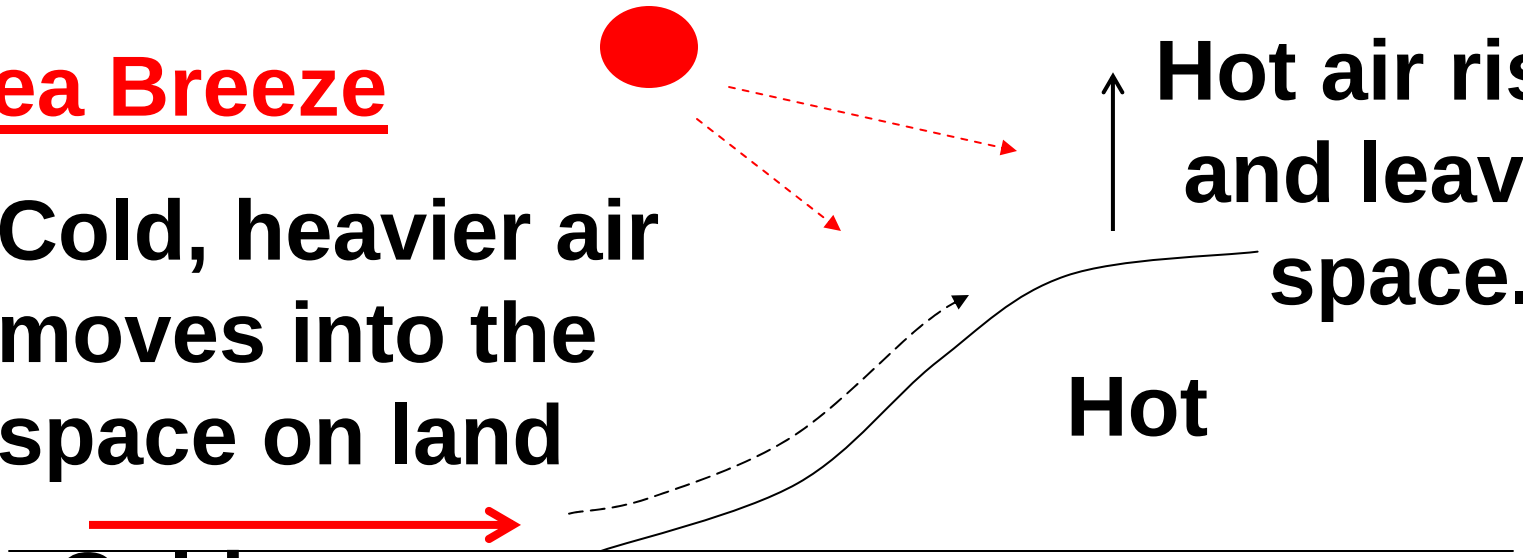
Fog also occurs over land – called "Radiation Fog". Humid air, often created by water vapour 'radiating' from plants, if at high altitudes or where significant cooling occurs, may experience condensation – fog. If it is cooler, heavier air than the warm air near sea level, so like a river, the fog flows down and may spill out to sea but only for a few miles before it starts evaporating.

Land and Sea Breezes

Hot land next to a coast where there is cold sea, has air heating and rising during the day, and cool heavier air comes off the sea to fill the gap being created by rising hot air. A light wind blows from sea onto the land – a "Sea Breeze". At night, high level land's air gets colder and heavier than coast level warmer air – the heavier air flows down and over the coast out to sea a few miles – it is "Land Breeze". Let's see …

Sea Breeze

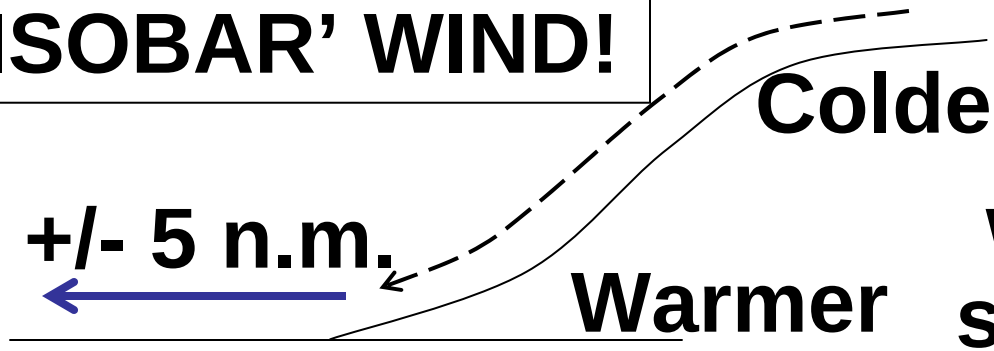
Cold, heavier air moves into the space on land



THESE ONLY HAPPEN WHEN THERE IS NO 'ISOBAR' WIND!

Land Breeze

Colder, heavier air up on high ground flows down like a river to lower warmer areas, and spills out to sea.



And That is That!

To really understand and know the "Marine Meteorology" in this presentation, be prepared to go through one or more sections several times. Then when at sea, watch what is happening, have regular checks (3 hourly?) on barometric changes, clouds, wind direction changes, and look for and get forecasts when possible.

Thank You!

Thank you for taking the time to work through this whole presentation on 'Marine Meteorology".

If you have any queries, ideas, or suggestions, or if you are aware of any errors, please email me at henton@sailingtrainingcd.com

www.sailingtrainingcd.com