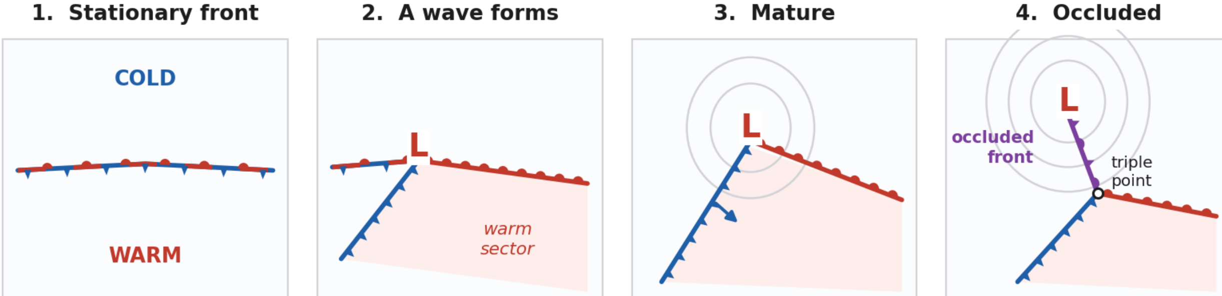
STUDY AID

Synoptic Meteorology

Reading the chart, reading the sky, and knowing which one is about to happen to you

Capt. Georgia Hilton

1. Stationary front | **2. A wave forms** | **3. Mature** | **4. Occluded**



cold air north, warm air south, the boundary going nowhere | a kink appears, a low is born, warm air pushes north into it | the low deepens, both fronts sharpen, the cold front closes the gap | the cold front wins, the warm air is lifted clear, the system fills and dies

Synoptic means ‘seen together’ — the whole weather pattern at one instant, drawn on one sheet. This is the half of meteorology you can actually work with on a bridge: what the air masses are, where they meet, what the fronts will do to you, and how to get wind speed and direction out of a chart without any instrument at all.

If you take four things from this guide, take these.

1. Tight isobars mean strong wind. Nothing on the chart tells you more, faster.

2. The wind veers through a cold front and backs then veers through a warm one. The shift tells you what has passed.

3. Back the wind and the low is on your left. You do not need a chart to find the centre.

4. The cold front runs about twice as fast as the warm front. That single fact is the whole life story of a depression.

SECTION 1

What synoptic means

Two charts, drawn at the same moment, at two different heights. Learn to read them together and the weather stops being a rumour.

A synoptic chart is a snapshot — every observation across a whole ocean, taken at the same hour and plotted on one sheet. From ships, buoys, aircraft, satellites and coastal stations, all of it valid at 0000, 0600, 1200 or 1800 UTC. That simultaneity is the point. It is what lets you see a pattern rather than a collection of local readings.

Chart	Height	What it shows	What you use it for
1000 mb surface analysis	about 300–360 ft — effectively sea level	Isobars, fronts, highs and lows, ship reports	Wind speed and direction, where the fronts are, what is about to arrive
500 mb upper air	about 18,000 ft	Contours of the height of the 500 mb surface, and the jet stream	Where the surface systems are being steered, and whether they will deepen or fill

The rule of thumb that makes the pair worth carrying: **surface systems go where the 500 mb flow sends them.** A deep upper trough with strong flow ahead of it will drive and deepen a surface low. A ridge aloft will sit on it and kill it. If the surface chart tells you what is happening, the upper chart tells you what happens next.

The grammar of a surface chart

Isobars — lines of equal pressure, drawn every **4 mb**. Standard sea-level pressure is **1013 mb**.

Spacing is speed. Isobars close together means a steep pressure gradient, which means strong wind. This is the single most useful thing on the sheet and you can read it across the room.

A low (L) is a depression: air spirals in and up, anticlockwise in the northern hemisphere. Cloud, rain, wind.

A high (H) is an anticyclone: air sinks and spirals out, clockwise in the northern hemisphere. Settled, light winds, and often poor visibility because nothing is stirring.

A trough is an elongated low without a closed centre; a **ridge** is the same for a high. Troughs carry weather; ridges suppress it.

A word about pressure tendency

The number matters less than the direction and the rate. A barometer reading of 1005 mb tells you very little on its own. A barometer that has fallen 6 mb in three hours tells you a great deal, and none of it is good. Log the pressure every watch and log the trend with it — rising, steady, falling, and how fast. On a passage with no chart at all, the tendency plus the wind shift is a workable forecast.

SECTION 2

Air masses

An air mass takes on the character of whatever it sat over, and it carries that character with it until something changes it.

Give a body of air long enough over a uniform surface — ice, ocean, desert, forest — and it comes into equilibrium with it. Cold ground makes cold, stable, dry air. Warm ocean makes warm, humid, unstable air. That is the whole classification, and it has only two axes: where it formed by latitude, and whether it formed over water or land.

Air mass	Code	Source region	Character	What it brings
Continental Arctic	cA	Polar ice and high polar land	Bitterly cold, very dry, very stable	Hard clear cold; sea smoke if it moves over open water
Continental Polar	cP	High-latitude land	Cold, dry, stable	Cold and clear, but unstable once it crosses warm sea
Maritime Polar	mP	High-latitude ocean	Cool, damp, unstable	Showers, good visibility between them, bumpy air
Continental Tropical	cT	Low-latitude land and desert	Hot, very dry, unstable at the surface	Haze, dust, and the dry side of a dryline
Maritime Tropical	mT	Low-latitude ocean	Warm, very humid	Fog and drizzle over cold water; thunderstorms over warm land

Modification — the part that catches people out

An air mass does not keep its label forever. What matters is the air mass **relative to the surface it is now crossing**.

Cold air over warm water is heated from below. It becomes unstable: convection, cumulus, showers, gusty winds, but usually good visibility. This is a polar airstream behind a cold front, and it is why the sky breaks up into towering cumulus once the front has gone through.

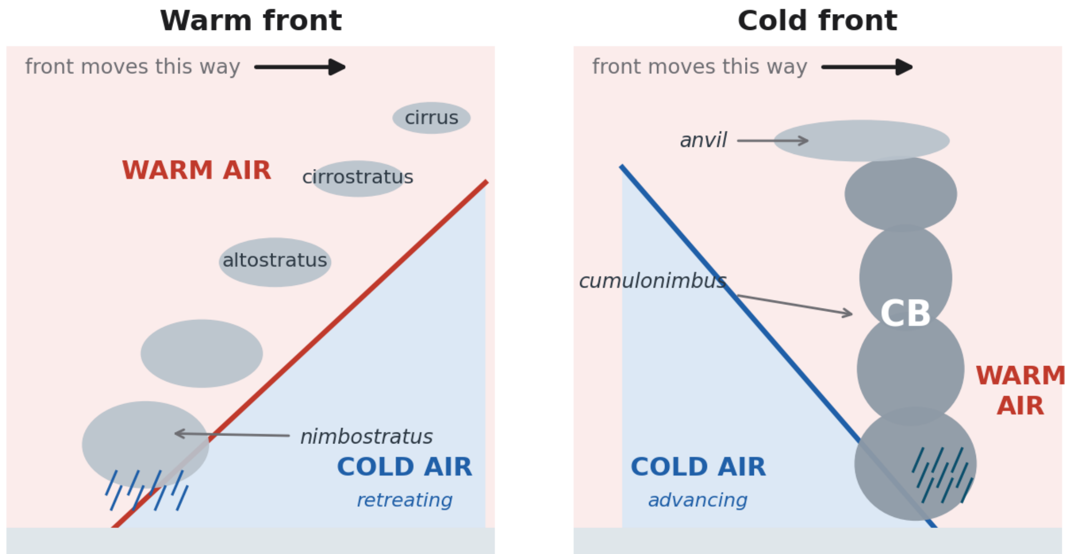
Warm air over cold water is cooled from below. It becomes stable and it condenses at the bottom: sea fog, low stratus, drizzle, and visibility that can go from ten miles to two cables without much warning. This is the dangerous one, because the weather it makes is quiet.

SECTION 3

Fronts

Where two air masses meet, neither one mixes politely. The boundary is a front, and fronts are where the weather is.

A **front** is the sloping surface between two air masses. What you see drawn on the chart is only the line where that sloping surface reaches the sea. It has depth as well as length, and the slope is very shallow: roughly **1 in 150** for a warm front and **1 in 75** for a cold front. The cold front is about twice as steep — which is exactly why it is about twice as violent.



slope about 1:150 · advancing 10–15 kt

wind BACKS ahead, VEERS on passage

cirrus → rain in 12–24 h · rain → front in ~5 h

slope about 1:75 · advancing 20–30 kt

wind VEERS sharply, all at once

twice the speed — so it runs the warm front down

Both fronts travel the same way — with the depression, generally eastward. Only the speed differs.

Figure 1 — Warm and cold fronts in cross-section. Vertical scale hugely exaggerated; the real slopes are far shallower than they can be drawn.

The direction they travel — get this straight first

Both fronts belong to the same depression and both travel with it, **generally eastward**, and generally poleward on the warm front and south-eastward on the cold front as the system wheels around.

They do **not** travel in opposite directions. If they did, they would separate and nothing would ever occlude.

The cold front simply moves about twice as fast — typically 20–30 kt against 10–15 kt for the warm front. It runs the warm front down from behind, and that overtaking is the entire life story of a depression.

The warm front, hour by hour

Warm air is less dense, so it cannot shove the cold air aside — it has to climb over it. That long, gentle climb gives you a cloud sequence that arrives in order, and the order is your clock.

- **Cirrus increasing** — the depression is roughly 12 to 24 hours away. Persistent contrails aloft say the same thing: they last when the air up there is already damp.
- **Cirrostratus, then altostratus** — the base is lowering and thickening. A halo round the sun or moon is cirrostratus and it is a good sign of what is coming.
- **Nimbostratus and steady rain** — the surface front is now about **5 hours** off. Rain gets heavier, wind freshens, base keeps dropping, visibility falls in the rain.
- **Wind BACKS** (anticlockwise) as the front approaches. Pressure falls steadily.

- **Passage** — rain eases to drizzle, temperature rises, pressure steadies, and the wind **VEERS**. You are in the warm sector: mild, damp, overcast, and often foggy over cold water.

The cold front, all at once

Cold air is dense and it undercuts. It does not negotiate. Instead of a long ramp you get a steep wedge that throws the warm air violently upward, and vertical development means cumulonimbus.

- Temperature drops, often sharply, and the pressure stops falling and starts to rise.
- **Wind VEERS suddenly** — a hard clockwise shift, sometimes through 90° in minutes. This is the shift that catches people out, and it is the one that puts a following sea on your beam.
- Squalls, heavy rain, possibly hail and lightning. It can reach gale force and it can do it without much warning.
- It does not last. There may be lingering light rain, then the sky breaks into cumulus congestus and altocumulus, visibility often becomes superb, and the sea stays rough long after the wind has eased.

> **Two more boundaries worth knowing**
>
> **Pre-frontal trough** — runs ahead of a cold front and often carries the more severe weather. Do not assume the worst arrives with the front itself; frequently it arrives an hour or two before it.
>
> **Squall line** — an organised line of severe thunderstorms, frequently along or ahead of a cold front. Treat it as the front for planning purposes.
>
> **Stationary front** — the boundary is going nowhere, by convention moving less than about 5 knots. Expect it to sit on you, and expect it to become the birthplace of the next depression.

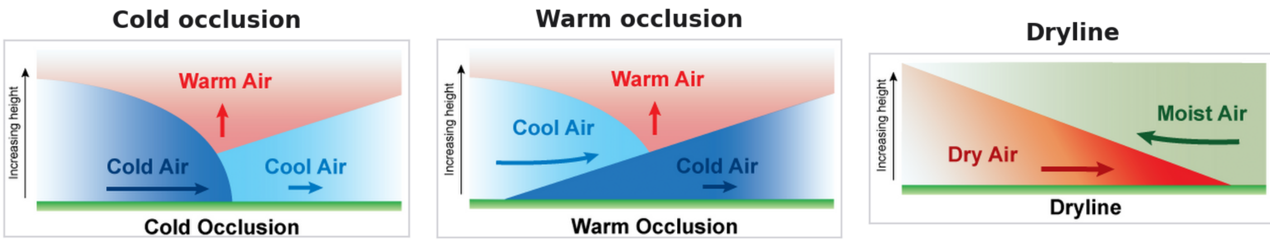
SECTION 4

Occlusions and the dryline

Cold fronts move faster than warm fronts. Sooner or later the cold front catches up, and when it does the depression starts to die.

When the cold front overtakes the warm front, the warm sector is lifted clean off the surface. That is an **occlusion**. The warm air was the fuel — it was the buoyancy that drove the whole circulation — so once it is cut off from the ground the system fills and decays.

> **But do not relax at the sight of an occluded front**
>
> A depression usually reaches its **greatest depth, and often its strongest surface winds, at or shortly after the onset of occlusion**. The filling comes afterwards.
>
> Occlusion tells you the system has stopped being fed — not that it has stopped being dangerous. Read it as the top of the curve, not the far side of it.



the air behind is COLDER than the air ahead — it undercuts

the air behind is MILDER than the air ahead — it rides over

dry air is denser — it undercuts the moist air and lifts it

Diagrams: NOAA JetStream (noaa.gov/jetstream)

Figure 2 — The two kinds of occlusion, and the dryline. In both occlusions the warm air ends up aloft; what differs is which of the two cold air masses is colder.

- **Cold occlusion** — the air arriving behind is **colder** than the air ahead, so it undercuts both and drives the warm air up from behind. Common over land in winter, and behind it the weather is showery and clear.
- **Warm occlusion** — the air arriving behind is **milder** than the air ahead, so it rides up over it instead. Common over the eastern ocean basins in winter, where the maritime air behind is relatively mild.
- **Either way the warm air is aloft.** That is what the word means. On the chart the occluded front is drawn purple, with triangles and semicircles alternating on the same side.
- **The triple point** is where the occluded front splits back into the separate warm and cold fronts. It is often the most active part of the system, and a new secondary low can form there.

The dryline

Not a temperature boundary at all — a humidity one. Dry air is denser than moist air at the same temperature, because a water molecule weighs less than the nitrogen and oxygen it displaces. So the dry air undercuts the moist air and lifts it, exactly as a cold front would, without much temperature contrast to warn you. Drylines fire violent storms and they are largely a continental phenomenon, but the physics is worth having: **humid air is light air**. Worth adding what that does *not* explain, though — a moist airstream on its own shifts surface pressure by only a millibar or two. The 10 or 20 mb fall ahead of a depression is dynamic: the flow aloft is removing mass from the column faster than the surface can replace it.

SECTION 5

The life of a depression

Every mid-latitude low runs the same four-act play. Learn the acts and you can place any chart you are handed.

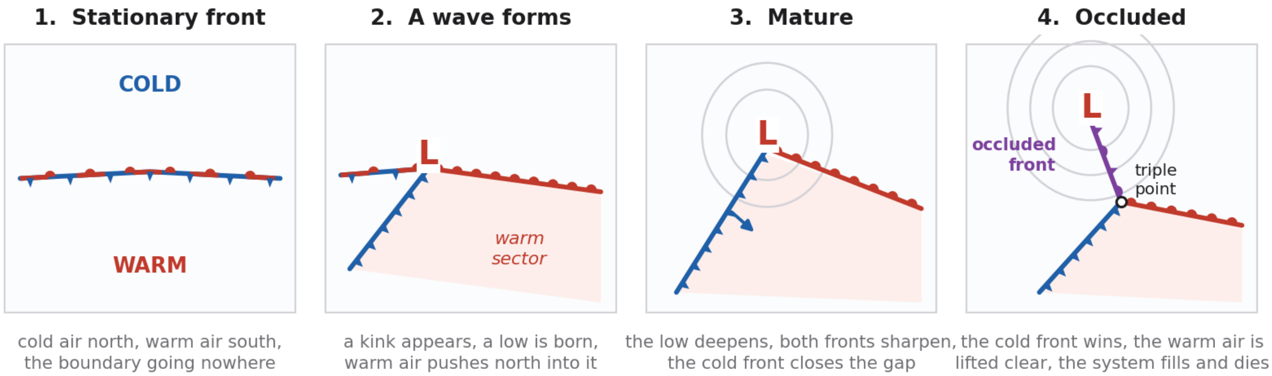


Figure 3 — Frontal wave to occlusion. Northern hemisphere; the whole system tracks generally eastward while this is happening, typically over three to five days.

1. The stationary front. Along the polar front, cold air from the north sits against warm air from the south with the boundary going nowhere. Nothing much is happening, but the temperature contrast is stored energy waiting for a trigger — usually a disturbance in the jet stream overhead.

2. A wave forms. A kink appears in the front. Warm air pushes north into the cold air on one side, cold air pushes south on the other, and pressure falls at the apex. A low is born. The kink now has two fronts: a warm front running east from the centre, and a cold front trailing back to the south-west, with the warm sector between them.

3. Mature. The low deepens, the isobars tighten, and both fronts sharpen. This is the stage that gives you the classic sequence — cirrus, lowering cloud, rain, the warm sector, then the cold front and the clearance. The cold front is already closing the gap.

4. Occluded, then gone. The cold front catches the warm front, starting at the centre and working outward. The warm air is lifted clear, the low fills, the winds ease, and the whole thing decays into a swirl of cloud with no fronts left in it. What survives is often a fresh wave forming further back down the trailing front — which is why depressions arrive in families, one behind another, each a little further south than the last.

What that means for you, on passage

The order of the weather tells you where you are in the system. Falling glass with backing wind and lowering cloud puts you ahead of a warm front. Steady glass, mild, murky and a veered wind puts you in the warm sector, and the cold front is coming.

Your position relative to the track decides your weather. Pass to the south of a northern-hemisphere low and you get the full sequence: warm front, warm sector, cold front, clearance, with the wind veering steadily through the whole thing. Pass to the north of it and you get no fronts at all — just thickening cloud, rain, a backing wind, and then a slow clearance.

A family of depressions is a week of weather, not a day. If one has just gone through and the glass starts falling again, look astern for the next one rather than assuming it is a blip.

SECTION 6

Convergence, divergence and why highs and lows exist at all

Air cannot pile up at a point. Everything that flows in at the bottom has to go out at the top, and that is the whole business.

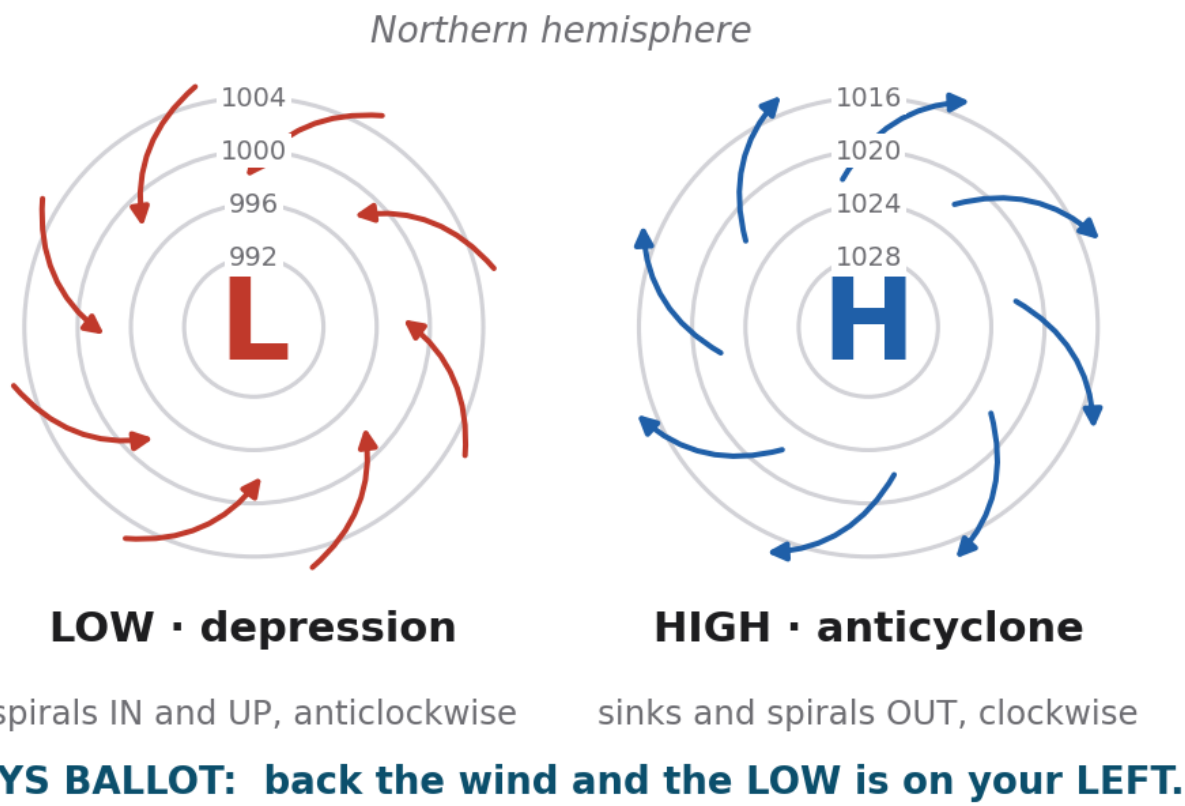


Figure 4 — Surface flow around a low and a high, northern hemisphere. Note that the wind crosses the isobars — inward around the low, outward around the high.

Mass continuity says that mass cannot be created or destroyed in a given volume. So when surface air converges into a low from all sides, it has nowhere to go but up. Rising air expands, cools, reaches its dew point, and condenses. That is why lows are cloudy, wet and windy, and it is the same reason a front — where dense air shoves in under lighter air and forces it up — produces cloud along its whole length.

A high is the same argument run backwards. Air converges aloft, sinks, and diverges outward at the surface. Sinking air is compressed and warms, its relative humidity falls, and cloud evaporates. Settled weather, light winds — and, because nothing is stirring the lower atmosphere, often haze, poor visibility and trapped fog.

> **The upper and lower levels are coupled**
>
> A surface low can only keep deepening if the air rising out of it is being **removed faster aloft than it is being supplied below**. That removal is upper-level divergence, and it happens in particular places relative to the jet stream.
>
> A surface high is maintained by **convergence aloft** feeding sinking air down into it.
>
> This is why forecasters look at the 500 mb chart before they commit to a surface forecast. The surface chart shows you the system; the upper chart shows you whether it is being fed or starved.

SECTION 7

The wind and the isobars

Why the wind blows along the isobars instead of straight down the gradient, and why the surface wind cheats.

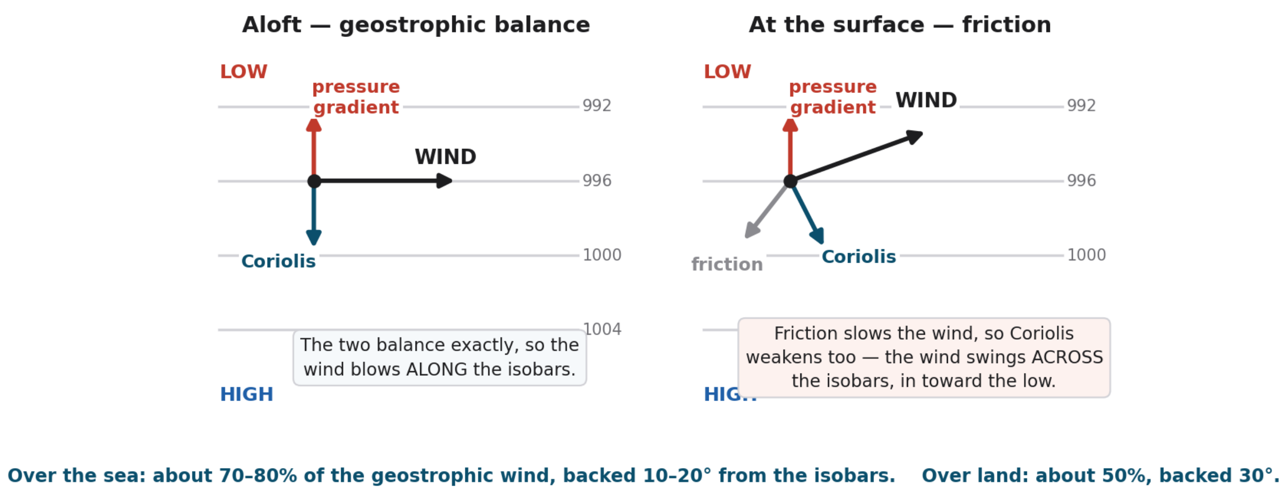


Figure 5 — The force balance. Aloft the wind runs parallel to the isobars; at the surface friction breaks the balance and the wind swings in toward the low.

Pressure pushes air from high toward low. That force — the **pressure gradient force** — acts at right angles to the isobars, and the tighter the isobars the stronger it is. Left alone, the wind would blow straight from high to low and pressure differences would even out in an afternoon.

But as soon as the air moves, Coriolis deflects it to the right (northern hemisphere). It keeps turning until the Coriolis force is pointing exactly opposite the pressure gradient force and the two cancel. At that point the air is moving at right angles to both — that is, **along** the isobars. This is the **geostrophic wind**, and above about 2,000 ft it is very nearly what you get.

At the surface, friction drags on the wind and slows it. A slower wind generates less Coriolis force, so Coriolis no longer balances the pressure gradient, and the wind swings back toward the low — it crosses the isobars instead of following them. That inward component is what feeds a depression, and it is why the flow spirals rather than circles.

Buys Ballot's Law — learn this one cold

Northern hemisphere: stand with the wind at your back. The low pressure is on your **LEFT**, and slightly **ahead** — because friction has already turned the surface wind inward across the isobars.

Southern hemisphere: wind at your back, low pressure on your **RIGHT**.

Some texts phrase it facing into the wind, which flips the answer. Pick one wording and stay with it. The point is that **the wind itself tells you where the centre is** — no chart, no forecast, no instrument.

Getting a wind speed off the chart

- Measure the perpendicular distance between adjacent isobars where it is **tightest** in your area — that is where the strongest wind is.
- Enter the geostrophic wind scale printed on the chart **at your latitude** with that spacing. What you read off is the **geostrophic** wind at about 600 m — the scale assumes straight isobars and applies no correction for curvature.
- **Over the sea**, the surface wind is roughly **70–80%** of that, backed **10–20°** from the isobars. **Over land** it is nearer **50%**, backed **30°**.
- So 50 kt of geostrophic wind at 600 m means about **35 kt at sea level** — and gusts that reach up and grab the full 50.
- **Curvature matters.** Around a low the flow is turning, so the gradient wind is **weaker** than geostrophic; around a high it is **stronger**. A tightly curved small low is not quite as vicious as its isobar spacing suggests, and the edge of a big high is windier than it looks.

If you have no scale to hand, the spacing itself is the message: isobars packed tightly enough that you would not want to draw another one between them mean gale force, and at that point you should be planning around it rather than measuring it.

SECTION 8

Forecasting from what you actually have

Bridge forecasting is not modelling. It is pattern, tendency and shift — three things you can get without a chart at all.

Suppose the download failed and the fax is down. You still have a barometer, a wind vane and a pair of eyes, and that is enough to make a useful twelve-hour call.

What you see	What it means	What is coming
Glass falling, wind **backs then VEERS**, cirrus thickening to cirrostratus	A warm front is approaching and the low will pass to your **north**	Rain in 12–24 h, then a mild murky warm sector, then a cold front
Glass falling, wind **backs and keeps backing**, cloud lowering, no warm sector ever arrives	The low is passing to your **south** — you are on its cold side	Rain, then a slow clearance. No fronts, and no clean wind shift
Glass falling, wind steady in direction, cloud lowering	The centre is heading more or less **straight for you**	Worst of the wind, and a rapid shift when the centre passes
Glass steady, mild, overcast, drizzle, wind veered	You are in the **warm sector**	The cold front, with a hard veer and squalls
Glass rising sharply, wind veered hard, temperature dropped, towering cumulus	The **cold front has passed**	Showers and good visibility, easing over 6–12 h — but check astern for the next one
Glass high and steady, light winds, haze	You are inside a **high**	More of the same; watch for fog rather than wind
Long low swell from a direction that does not match your wind	A big system a long way off, and this is its first message	In the tropics, treat as a possible TRS until proved otherwise

Two habits worth building

Log pressure and wind direction every watch, without fail. A single reading is nearly worthless; a six-hour trace is a forecast. You are looking for the rate of fall and the sense of the shift, and neither is visible in a snapshot.

Write down what the sky is doing, not just what the instruments say. Cloud type and sequence is real data. It was the only data anyone had for three hundred years, and it still arrives before the front does.

TEAR THIS OUT

The Synoptic Card

THE CHART

Isobars every **4 mb**. Standard sea level **1013 mb**. **Tight isobars = strong wind.**

1000 mb chart = the surface, what is happening. **500 mb** chart = 18,000 ft, what happens next.

Surface wind over the sea ≈ **70–80%** of the 600 m geostrophic wind, backed **10–20°**. Over land ≈ 50%, backed 30°.

Curved flow: **weaker** than geostrophic round a low, **stronger** round a high.

BUYS BALLOT — NORTHERN HEMISPHERE

Wind at your back → **LOW on your LEFT**, slightly ahead. (Southern hemisphere: LOW on your right.)

FRONTS

VEER = clockwise (NE→E→SE). **BACK = anticlockwise** (NE→N→NW).

Warm front: backs ahead, **veers** on passage. Slope 1:150, 10–15 kt. Cirrus → rain 12–24 h; rain → front ~5 h.

Cold front: veers sharply, all at once. Slope 1:75, 20–30 kt. Short, hard, then it clears.

Both travel the same way, with the depression. The cold one is twice as fast — which is why it occludes.

Occluded: warm air lifted clear of the surface. The system is now filling and dying.

AIR MASSES

cA / cP / mP / cT / mT — continental or maritime, arctic, polar or tropical.

Cold air over warm water → unstable: cumulus, showers, gusts, **good** visibility.

Warm air over cold water → stable: **fog**, stratus, drizzle, visibility gone. This is the quiet dangerous one.

LIFE OF A DEPRESSION

Stationary front → wave forms → mature → occluded → fills and dies. Three to five days.

Low passes NORTH of you: full frontal sequence, wind backs then **veers** and keeps veering. **Low passes SOUTH of you:** no fronts, wind **backs and stays backed**, slow clearance. **Whether the back is followed by a veer is the whole test.**

They come in **families**. Glass falling again after a clearance means look astern, not up.

NO CHART? FORECAST ANYWAY

Falling glass + backing wind that then **veers** = warm front, low passing north of you. Backing that **never veers** = low passing south of you.

Falling glass + **steady** wind direction = the centre is coming straight at you.

Rising glass + hard **veer** + temperature drop = the cold front has gone through.

Log pressure and wind every watch. The trend is the forecast.

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