

ADVANCED MARINE WEATHER

The Night-Watch Lecture — with Diagrams, Tables & Drills

The full night-watch lecture, section by section, each followed by the diagrams, tables and boxed rules that distil it. Read the narrative to understand it; use the reference to teach and remember it.

1 · The Atmosphere as a Heat Engine

Let's begin where any honest discussion of weather must begin: with the admission that the whole apparatus is a heat engine. That's all it is. The sun pours energy onto a rotating, tilted, unevenly painted ball — ocean here, desert there, ice at the ends — and the atmosphere and ocean spend their entire existence trying, and forever failing, to even that heat out.

Every wind you've ever leaned into, every front that's soaked you, every calm that's left you rolling your guts out in a windless swell — all of it is the atmosphere moving heat from where there's too much to where there's too little. Hold that idea like a compass rose in the back of your mind, because everything else hangs off it. Weather isn't a collection of phenomena. It's one process, heat transport, wearing a thousand costumes.

The equator takes sunlight nearly head-on all year. The poles get it at a slice, spread thin across the curve of the earth, and for half the year they get none at all. So there's a permanent surplus of heat in the tropics and a permanent deficit at the poles, and the temperature difference between them is the voltage that drives the entire circuit.

If the earth didn't rotate, that circuit would be simple — hot air rising at the equator, flowing aloft to the poles, sinking there, returning along the surface as one vast convection loop per hemisphere. One cell. A steady equator-to-pole surface wind. Beautifully simple, and completely wrong, because the earth does rotate. And rotation is the second great fact that shapes everything you see from the deck.

- The tropics run a permanent heat **surplus**; the poles a permanent **deficit**.
- The temperature difference between them is the **voltage** that drives all weather.
- A non-rotating earth would need only one convection loop per hemisphere — a single cell.
- Because the earth spins, that simple loop breaks apart. Rotation is the second great fact.

KEY RULE

All weather is the transport of heat from surplus to deficit. Hold that idea like a compass rose; everything else hangs off it.

2 · The Coriolis Effect

Now, the Coriolis effect — the most misunderstood force in practical meteorology, and most explanations of it do more harm than good. It is not a force in the ordinary sense. Nothing pushes the air sideways.

What happens is this: you, your vessel, your chart, your whole sense of a fixed north, are standing on a spinning platform, and you insist on measuring motion relative to that platform. Air set in motion travels, as far as the universe is concerned, in a nearly straight line. But the earth turns underneath it while it travels. So from our rotating point of view, the air appears to curve — right in the Northern Hemisphere, left in the Southern.

The deflection is zero at the equator, strongest at the poles, and proportional to how fast the air is already moving. Slow air, weak deflection. Fast air, strong deflection. It acts always at right angles to the motion, so it can bend a wind but never speed it or slow it. Fix that firmly: Coriolis turns, it does not drive.

- Air travels near-straight through space; the earth rotates under it as it goes.
- Apparent deflection: to the **right** in the Northern Hemisphere, **left** in the Southern.
- **Zero** at the equator, **strongest** at the poles.
- Proportional to the speed of the air — fast air deflects more.
- Acts at right angles to motion, so it can only turn a wind, never speed or slow it.

KEY RULE

Coriolis **turns**; it does not **drive**.

3 · The Three-Cell Circulation

Put those two facts together — the heat surplus at the equator, and the turning — and the single simple convection cell breaks into the structure you actually navigate under.

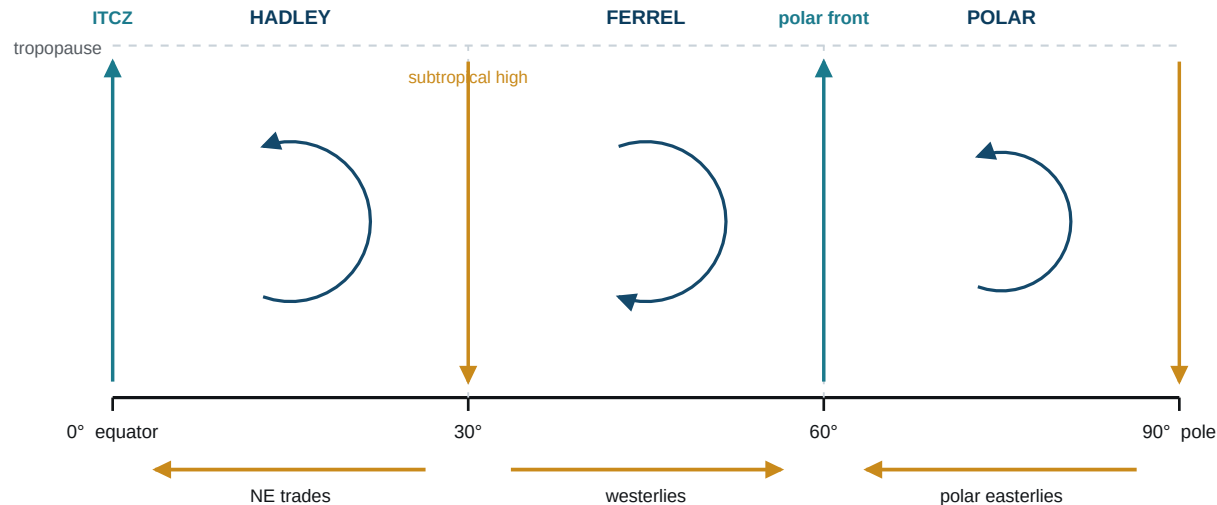
The air rising at the equator flows poleward aloft, but as it goes, the deflection bends it further and further east, until by about thirty degrees of latitude it's running almost due east and has stopped making poleward progress altogether. It piles up there, cools, and sinks. That's the horse latitudes — the subtropical high-pressure belts. Descending air warms as it compresses, and warming air holds more moisture rather than less, so it dries as it comes down. That's why the great deserts of the world sit in a ring around thirty north and thirty south. And it's why the Bermuda-Azores High and the Pacific High sit parked over the subtropical oceans, dominating everything a mariner does in those waters.

From that sinking region the air splits at the surface. Some runs back toward the equator, deflecting right in the Northern Hemisphere to become the northeast trades, left in the Southern to become the southeast trades. Where they meet: the Intertropical Convergence Zone. The doldrums. Rising air, towering convection, squalls, and maddening calms.

The rest runs poleward from that high, deflecting right again into the prevailing westerlies of the mid-latitudes — the belt where you and I do most of our sailing and take most of our punishment. Further north it meets cold polar air spilling equatorward, and that collision zone is the polar front: the birthplace of every mid-latitude depression that ever ruined a passage plan.

So — three cells per hemisphere. Hadley, Ferrel, Polar. Not tidy, not fixed, migrating north and south with the season as the sun's overhead point wanders. But that's the skeleton. Everything else is muscle hung on it.

- **Hadley cell (0–30°)**: rises at the equator, sinks at the horse latitudes.
- **ITCZ / doldrums**: rising air, towering convection, squalls and calms where the trades meet.
- **Horse latitudes (~30°)**: sinking, warming, drying air — the subtropical highs, and the world's deserts. The Bermuda-Azores and Pacific Highs live here.
- **Trades**: surface flow back toward the equator — NE in the north, SE in the south.
- **Westerlies (30–60°)**: the mid-latitude belt where we take most of our weather.
- **Polar front (~60°)**: cold polar air meets warm subtropical air — the nursery of depressions.
- The whole pattern migrates north and south with the season.



Hemisphere cross-section (Northern): rising air at the equator (ITCZ) and along the polar front; sinking air at the subtropical high (≈30°) and the pole. The lower arrows are the surface wind belts, running toward or away from the equator.

4 · Pressure & the Barometer

Now come down from the planetary scale to the scale you work in. The barometer measures the weight of the column of air above you. That’s all. High pressure, more air stacked overhead, generally sinking, generally settled. Low pressure, less air, generally rising, generally unsettled. But here’s what matters, and what the old hands drum into you: it isn’t the height of the barometer that tells you the weather, it’s the rate of change. A glass sitting at 1005 and steady is telling you something benign. A glass at 1015 falling three millibars in three hours is telling you something is coming, and coming hard.

Keep these thresholds. A fall of one to two millibars in three hours means a system approaching — worth attention. Three to four millibars in three hours means a vigorous system, gale force likely. Five or more in three hours means a storm, and you should already be taking action rather than thinking about it. And the reverse holds: a barometer that rises too fast is not good news either. A sharp rise behind a cold front brings its own squalls and a hard, gusty northwesterly.

There’s an old rule worth carrying. Long foretold, long last; short notice, soon past. A slow, steady, grinding fall over a day and a half means a big system that will sit on you for days. A violent drop over three hours means something fast and sharp that will be through and gone by morning.

KEY RULE

Read the **rate of change**, not the height of the glass.
Long foretold, long last; short notice, soon past.

3-hour fall	What it means	What you do
1–2 mb	System approaching	Take note; watch the trend
3–4 mb	Vigorous system — gale likely	Prepare the vessel; secure for weather
5 mb or more	Storm developing	Act now — don’t deliberate
Sharp rise	Cold front through; gusty NW’ly	Expect squalls behind the front

5 · Wind — Gradient, Geostrophic & Buys Ballot

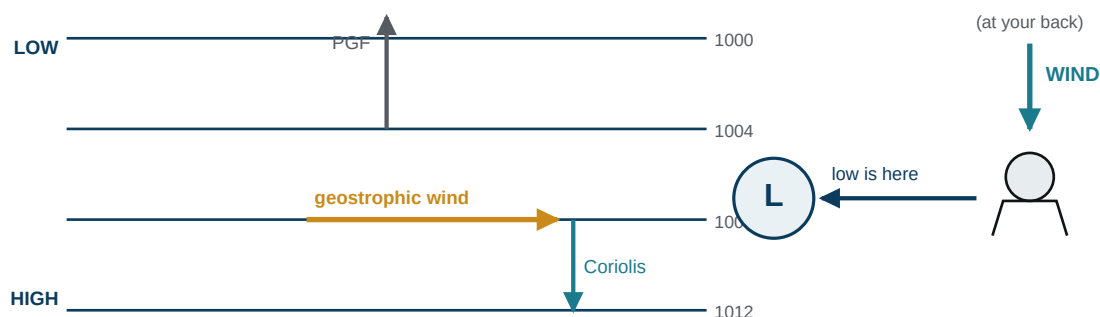
Why does wind blow at all? Pressure difference. Air moves from high toward low, and the steeper the pressure gradient, the harder it blows. On a synoptic chart, the isobars are contour lines of pressure, and their spacing is your wind speed: tight isobars, strong wind; slack isobars, light air. That's the single most valuable thing on a surface analysis, and you can read it at a glance from across the chart table.

But the wind does not blow straight from high to low, and here's where Coriolis returns. Air starts moving down the gradient, and the moment it moves, the deflection begins bending it right. It keeps bending until the pressure gradient force pulling it inward is balanced by the Coriolis deflection pushing it outward — and at that point, the air is running parallel to the isobars, not across them. That's geostrophic wind. Down at the surface, friction slows the air, weakens the deflection, and lets the wind fall back across the isobars toward the low — by about fifteen degrees over open water, more like thirty over land, and a touch weaker.

From this falls out the single most practical rule in all of marine weather. Buys Ballot's Law. In the Northern Hemisphere, stand with your back to the true wind, and the low pressure is on your left — roughly to your left and slightly behind. In the Southern Hemisphere, reverse it: back to the wind, low on your right.

Think about what that gives you. Standing on deck, with no chart, no forecast, no radio, you can locate the centre of the system that's working you. And by taking that bearing repeatedly over some hours and watching how it shifts, you can work out whether the thing is coming at you, passing ahead, or passing behind. That rule is three hundred years old and it still works in the middle of the ocean with the electronics dead.

- **Isobar spacing is wind speed:** tight isobars, strong wind; slack isobars, light air.
- **Geostrophic wind:** aloft, above friction, wind blows along the isobars, not across them.
- **Surface friction** backs the wind across the isobars toward the low — $\sim 15^\circ$ over sea, $\sim 30^\circ$ over land — and weakens it.



Northern Hemisphere: back to the wind, low on the LEFT

Balance aloft: pressure-gradient force out-balanced by Coriolis; the wind ends up parallel to the isobars.

Find the low with no instruments: back to the wind, low on the left (N. Hem.).

KEY RULE

Buys Ballot's Law. Northern Hemisphere: back to the true wind, the low is on your **left** and slightly behind.

Southern Hemisphere: low on your **right**.

Take the bearing repeatedly — how it shifts tells you if the system is coming for you.

6 · The Mid-Latitude Depression

The mid-latitude low is the machine that generates most of your bad days. Start at the polar front — that boundary where cold polar air meets warm subtropical air. It isn't a smooth line; it's a shear zone, and shear zones are

unstable. A small wave forms on it, a kink where warm air noses poleward and cold air noses equatorward. If conditions are right, that kink doesn't damp out. It amplifies.

Pressure falls at the kink. Air begins circulating around it — anticlockwise in the Northern Hemisphere. The warm air advances on the eastern side, riding up over the cold air ahead of it: your warm front. On the western side, cold air undercuts the warm air, shovelling it upward: your cold front. The warm sector is the wedge of mild, moist air between them.

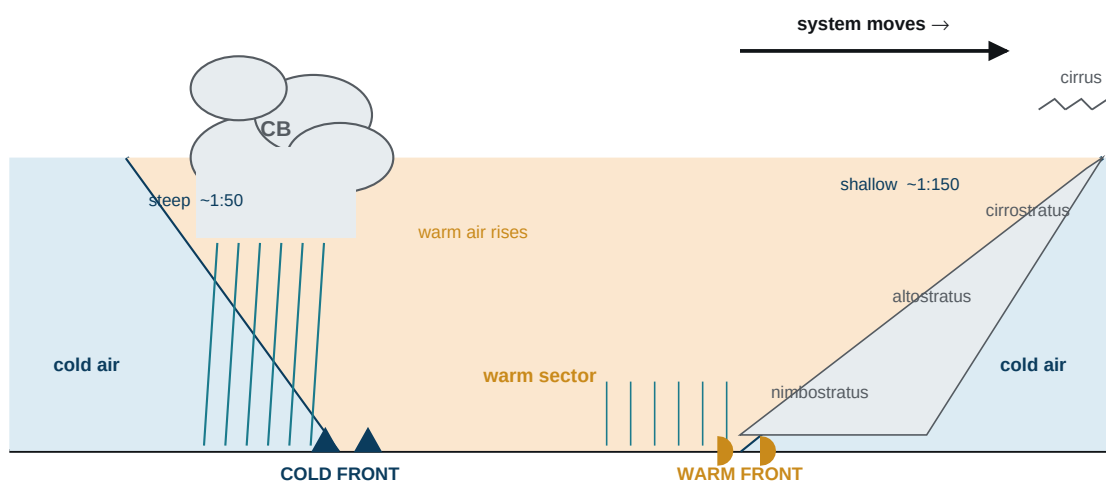
The warm front has a shallow slope — one in a hundred and fifty. Warm air can't shove cold air aside, so it climbs gently over the top, and that long ascent gives a slow, orderly, readable sequence, the same every time. First cirrus, mare's tails, six hundred miles ahead, often a full day early — thickening and lowering is your first warning. Then cirrostratus, the milky veil with a halo round sun or moon. Then altostratus, the sun a watery blur; then nimbostratus and steady rain, wind backing and freshening, glass falling, visibility down.

Then the surface warm front passes and everything changes at once. Rain eases, temperature jumps, the barometer steadies, and the wind veers — clockwise in the north. You're in the warm sector: mild, murky, poor visibility, perhaps sea fog over colder water.

The cold front is nothing like its sibling. Its slope is steep — one in fifty. Cold dense air acts like a plough, driving under the warm air and hurling it violently upward: deep convection, cumulonimbus, a narrow savage band of squalls, heavy rain, thunder, hail. The passage is abrupt — wind veers sharply, often forty-five to ninety degrees in minutes, the squall can double the wind speed with no warning, the glass turns and rises, temperature drops hard. Behind it the sky opens into a scoured, bright, showery northwesterly, cold and gusty, with a nasty steep sea because the wind has shifted across the old swell.

That cross sea is worth dwelling on. For some hours after the cold front you have a strong new northwesterly running across the old southwesterly swell — the most dangerous water in the whole depression. Not the strongest wind, the most confused sea. More vessels are hurt there than in the front itself.

The last act is occlusion. The faster cold front catches the warm front, lifts the entire warm sector clear of the surface, and the low, cut off from its warm air, fills and dies. Life cycle: wave, deepening, mature, occluded, dying — two to five days. And they come in families, one after another down the polar front, each riding the jet stream east. That's why one bad system so often means several.



Vertical section through a depression (system moving right). Shallow warm-front ramp with its long, orderly cloud sequence ahead; steep cold front driving deep convection behind.

	Warm front	Cold front
Slope	Shallow (~1:150)	Steep (~1:50)
Cloud	Layered: cirrus → cirrostratus → altostratus → nimbostratus	Convective: towering cumulonimbus
Precip	Long, steady rain well ahead	Narrow, violent squall band
Wind shift	Backs then veers as it passes	Veers sharply — 45–90° in minutes
Pressure	Falls steadily, then steadies	Stops falling, then rises
Temp	Rises into the warm sector	Drops hard behind

- **Approach:** high cirrus a day out; halo round sun or moon; cloud lowers and thickens; rain sets in; barometer falls; wind freshens and backs.
- **Warm sector:** mild, murky, poor visibility, often sea fog.
- **Behind the cold front:** bright, cold, gusty NW'ly with towering cumulus and showers.
- **Occlusion:** the faster cold front catches the warm front, lifts the warm sector aloft, and the low fills and dies. Life cycle: wave → deepen → mature → occlude, over 2–5 days.
- Depressions travel in **families** down the polar front — one usually means several.

ON DECK

The worst water in the whole system is the **cross sea** in the hours after the cold front — a hard new NW'ly running across the old SW'ly swell. More vessels are hurt there than in the front itself. It is confusion, not strength, that does the damage.

7 · The Jet Stream & Rossby Waves

Let's go up to the jet stream, because it governs the whole business and it's where the real forecasting skill lives. The jet is a narrow ribbon of very fast wind near the tropopause, thirty thousand feet or so, running west to east, sometimes a hundred and fifty knots or more. It exists because of the temperature contrast across the polar front; a strong contrast means a strong jet. It's the steering current: surface lows travel roughly along it, at roughly half its speed.

But it does more than steer. Where the jet diverges aloft — where air spreads apart — it evacuates the air column faster than the surface can supply it, surface pressure falls, and the depression deepens. A low under a divergent region of a strong jet will bomb out; the same low under a flat, unremarkable jet will amble along and fizzle.

And the jet meanders, developing great north-south Rossby waves that set the pattern for a week at a time. Running straight west to east — zonal flow — systems race across quickly, one after another, weather changing fast. Buckled into deep meridional waves, systems slow down, dig in, and park; that's your week of the same miserable thing, or a blocking high that won't shift. Zonal, pick your gap. Meridional, expect whatever you've got to persist.

- The jet is the **steering current**: surface lows track along it at roughly half its speed.
- Where the jet **diverges aloft**, it evacuates the air column and the surface low deepens — this is what turns an ordinary low into a bomb.
- **Zonal flow** (straight, W–E): a fast parade of systems, weather changing quickly.
- **Meridional flow** (deep N–S waves): systems slow, dig in, and park — or a blocking high sets up.

KEY RULE

Zonal flow: pick your gap between fast movers. Meridional flow: whatever you've got will stay — plan for persistence.

8 · Tropical Cyclones

Tropical systems are a wholly different animal, and confusing the two kinds of storm causes real harm. A mid-latitude depression is powered by temperature contrast — a frontal system, cold-cored, strengthening with height. A tropical cyclone has no fronts at all: warm-cored, powered by the latent heat released as water vapour condenses, and strongest at the surface, weakening with height. Different engine, different structure, different tactics.

Genesis requires several things at once: sea surface temperature of about twenty-six and a half Celsius, eighty Fahrenheit, through a good depth; a pre-existing disturbance to organize around, often an easterly wave off Africa; enough distance from the equator, five degrees or so, for Coriolis to start the rotation — which is why you never see a hurricane on the equator; moist mid-levels; and critically, low vertical wind shear, because shear tears the developing core apart before it can organize. Note the difference from a supercell, where moderate shear helps — in the tropics, shear is purely destructive to the system as a whole.

The structure: the eye, calm and clear, ten to forty miles across; the eyewall around it, the ring of most violent wind and heaviest rain, the strongest winds on the planet's surface; spiral rainbands feeding inward, sometimes with tornadoes; and the storm's sea running hundreds of miles beyond its wind.

Now the mariner's part, the dangerous semicircle, and this deserves precision. Take a Northern Hemisphere hurricane moving northwest, winds circulating anticlockwise. On the right of the track, the rotational wind and the storm's forward motion run the same way and add; on the left they oppose and partially cancel. A hundred-knot circulation moving at twenty gives roughly a hundred and twenty on the right, eighty on the left — the difference between very bad and catastrophic.

But the arithmetic isn't the whole of it. On the right side the wind veers as the storm passes and tends to drive you into its path, ahead of the centre. On the left it backs and tends to set you away. So the right is dangerous twice over: stronger wind, and a wind that pushes you where you least want to go. Right side dangerous, left side navigable — and in the Southern Hemisphere everything mirrors, the left side dangerous.

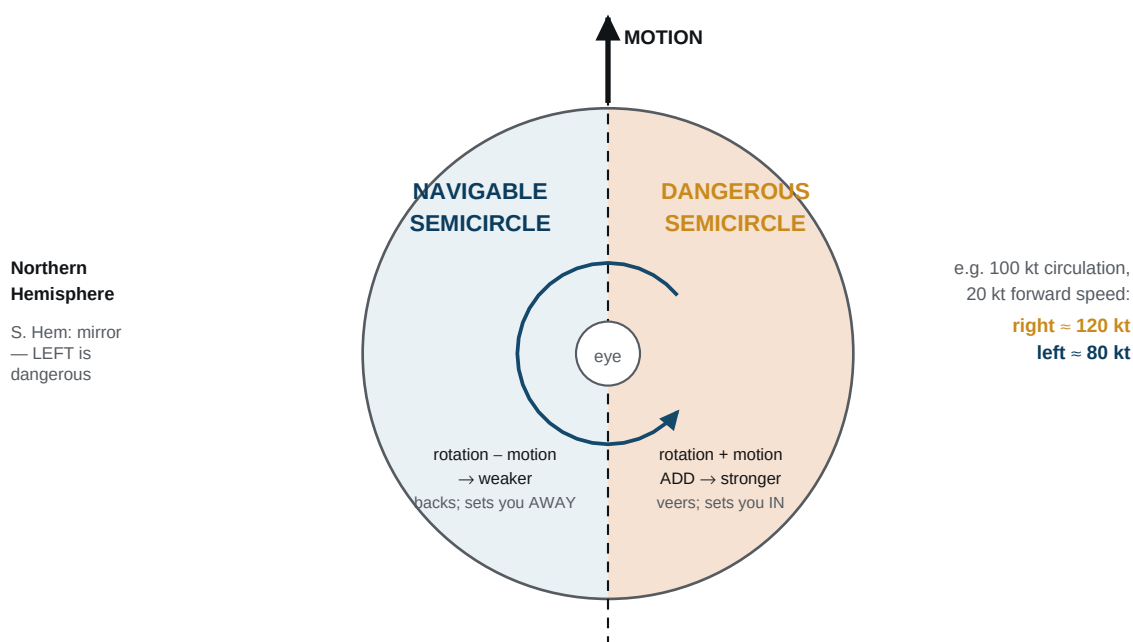
How do you know which side you're on? Watch the wind over a few hours. Veering steadily — east, southeast, south — you're in the dangerous right semicircle. Backing — east, northeast, north — the navigable left. And if the direction holds steady while the glass falls and the wind builds, that is the worst news of all: you're on the track, dead ahead of the centre.

The tactics, Northern Hemisphere: in the dangerous semicircle, wind on the starboard bow and make what way you can, out of the path; in the navigable semicircle, wind on the starboard quarter and run; directly in the path, wind on the starboard quarter and run for the navigable side. Everything reverses in the south — port bow, port quarter. And know the thirty-four-knot rule: plot the radius at which winds reach thirty-four knots, add a growing margin for forecast error, and stay outside it. You don't dodge a hurricane at close quarters. You avoid it two days out, with sea room and the decision made early.

	Mid-latitude low	Tropical cyclone
Engine	Temperature contrast (fronts)	Latent heat of condensation
Core	Cold-cored, strengthens with height	Warm-cored, weakens with height

	Mid-latitude low	Tropical cyclone
Fronts	Yes — warm, cold, occluded	None
Shear	Moderate shear helps organize	Shear is purely destructive

- **Genesis needs, all at once:** sea surface $\geq -26.5^{\circ}\text{C}$ / 80°F through depth; a seed disturbance; $\geq 5^{\circ}$ off the equator for rotation; moist mid-levels; and **low wind shear**.
- **Structure:** calm clear **eye**; the **eyewall** ring of most violent wind and rain; spiral **rainbands** feeding in, sometimes with tornadoes.



Northern Hemisphere storm. On the right of the track, rotation and forward motion add and the wind sets you into the path — the dangerous semicircle. On the left they oppose and set you away.

Wind over a few hours	Where you are (N. Hem.)	Action
Veers (E→SE→S)	Dangerous right semicircle	Wind on starboard bow , make way out
Backs (E→NE→N)	Navigable left semicircle	Wind on starboard quarter , run
Steady, glass falling	On the track, ahead of centre	Get wind on starboard quarter, run for the navigable side

ON DECK

Southern Hemisphere: mirror everything — the **left** side is dangerous; use the **port** bow and quarter. You do not dodge a hurricane at close quarters. You avoid it **two days out**, with sea room and the decision made early. Plot the 34-knot radius and add a growing margin for forecast error.

9 · Local Effects

Now the things that happen at your scale — the local phenomena no synoptic chart will ever show you. Land heats faster than water by day and cools faster by night, because water has enormous thermal inertia and mixes its heat through depth. By day the land warms, air over it rises, pressure falls slightly, and cooler air flows in off the water — the sea breeze. It starts late morning, builds through the afternoon, peaks mid-afternoon, dies at sunset, can reach fifteen or twenty knots, and on a sunny coast it overrides a light gradient wind. At night the process

reverses, weaker: a light land breeze draining seaward, strongest just before dawn.

Katabatic winds are the serious cousin. Cold dense air pools on high ground — a plateau, a glacier, a mountain — and when it spills down a valley or fjord, gravity accelerates it and the terrain funnels it. These arrive without warning, at gale force or worse, on a night that looks perfectly benign. The Mediterranean has a whole vocabulary for them: the mistral down the Rhône, the bora off the Dinaric Alps into the Adriatic. Anchorages below high ground with a valley leading down deserve real respect on clear, cold, calm nights — exactly the conditions in which cold air pools.

- **Sea breeze:** land heats faster than water by day; cool air flows in off the sea. Builds late morning, peaks mid-afternoon, dies at sunset; 15–20 kt is common. It overrides a light gradient wind.
- **Land breeze:** the weaker night reversal — air drains seaward, strongest just before dawn.
- **Katabatic wind:** cold dense air pools on high ground and pours down a valley or fjord, accelerated by gravity and funneled by terrain. The Mediterranean *mistral* and Adriatic *bora* are classics — gale force or worse on a night that looks benign.

ON DECK

Give real respect to anchorages below high ground with a valley leading down — especially on clear, cold, calm nights, which are exactly when cold air pools and spills.

10 · Fog

Fog is where a lot of mariners come unstuck. Two main kinds, and they behave differently. Advection fog is warm moist air moving over colder water, cooled from below to its dew point — your sea fog, and the dangerous one, because wind does not disperse it. Wind actually helps it: it keeps the moist air coming and mixes the cooling upward. Advection fog can hold in twenty knots of breeze and lie over hundreds of miles of ocean for days. The textbook case is the Grand Banks, where warm Gulf Stream air meets the cold Labrador Current.

Radiation fog is a land phenomenon: the ground cools at night under a clear sky, chills the air above it, and fog forms in the low ground. It needs calm, and it burns off with the morning sun — it drifts over harbours and estuaries at dawn and clears by mid-morning. Much less dangerous, much less persistent. The practical test for both: compare air temperature to sea temperature. When the dew point reaches the sea surface temperature, expect fog. Watch that gap close and you have your warning before you lose the visibility.

	Advection fog (sea fog)	Radiation fog
Cause	Warm moist air over colder water	Land cools at night, chills air above it
Wind	Persists — even helps it; can hold in 20 kt	Needs calm; wind disperses it
Extent	Hundreds of miles, days at a time	Local, low ground, estuaries
Danger	The dangerous one at sea	Burns off with the morning sun
Classic	Gulf Stream air over the Labrador Current — the Grand Banks	Harbours and rivers at dawn

KEY RULE

When the **dew point** of the air reaches the **sea surface temperature**, expect fog. Watch that gap close and you have your warning before you lose the visibility.

11 · The Limits of Forecasting

Two more things, and then let me bring this in to anchor. Every forecast you read comes from a numerical model — a fluid-dynamics simulation on a grid — and every model has three unavoidable weaknesses. Finite resolution: anything smaller than a grid cell — convection, squalls, the sea breeze, the katabatic — is not simulated but parameterized, approximated by rule of thumb. Imperfect initial conditions, because the ocean is very thinly observed. And chaos: small errors grow exponentially, so useful skill runs to about five days for the broad pattern, and the specifics degrade far sooner.

Which is why ensemble forecasting exists — run the model many times with slightly perturbed starting conditions and watch the members diverge. If they agree, confidence is high. If they scatter by day three, the atmosphere is in a state where small differences matter enormously, and no amount of staring at a single run will save you. The spread is the information: when models disagree about a track, plan for the envelope, not the average.

And second, the reason you look out of the wheelhouse as well as at the screen. Your barometer, your eyes, your thermometer and the sea give you truth at your position, right now; the model gives you pattern over the region, in the future. The forecast tells you what ought to be happening; the instruments tell you what is. When the two disagree, the instruments win, every time, because the atmosphere is under no obligation whatsoever to match the model.

Here's the old cross-check to sleep on. Take Buys Ballot — back to the wind, low on your left in the north — and compare that bearing with where the forecast puts the low. If they agree, you understand your situation and can trust the next move. If they disagree by a significant angle, something is displaced or deeper or slower than forecast; reason from your own observations until the two come back together. Use the model for the shape of things. Use your senses for the truth of things. And when they part company, believe the sea.

- **Finite resolution:** anything smaller than a grid cell — squalls, sea breeze, katabatic wind — is not simulated but approximated by rule of thumb.
- **Sparse data:** the ocean is very thinly observed, so the starting point is imperfect.
- **Chaos:** small errors grow exponentially. Useful skill runs to about five days for the broad pattern; the specifics fade far sooner.
- **Ensembles:** run the model many times with nudged starting conditions. If members agree, confidence is high; if they scatter, the atmosphere is touchy — **the spread is the information.**

KEY RULE

Use the model for the **shape** of things and your senses for the **truth** of things. When they disagree, **believe the sea** — the atmosphere is under no obligation to match the model.

That's the tour: heat engine, rotation, circulation, pressure, wind, depressions, fronts, the jet, tropical systems, the semicircles, local effects, fog, and the honest limits of forecasting. What follows is the whole of it, boiled down to twelve lines.

12 · Say These Until They Are Automatic

Twelve lines. If a student can recite these cold, they carry the whole guide in their head.

- | | |
|---|--|
| 1. Weather is heat moving from surplus to deficit. | 7. The cross sea after the cold front does the damage. |
| 2. Coriolis turns; it does not drive. | 8. Right semicircle dangerous, left navigable — Northern Hemisphere. |
| 3. Isobar spacing is wind speed. | 9. Avoid the storm two days out, not two hours out. |
| 4. Read the rate of change, not the height of the glass. | 10. Dew point up to sea temperature — expect fog. |
| 5. Long foretold, long last; short notice, soon past. | 11. The spread is the information. |
| 6. Back to the wind, low on the left — Northern Hemisphere. | 12. When the model and the sea disagree, believe the sea. |

The whole discipline in one habit

Take Buys Ballot — back to the wind, low on your left — and compare that bearing with where the forecast puts the low. If they agree, you understand your situation and can trust the next move. If they disagree, something is displaced or deeper than forecast — reason from your own observations until the two come back together. Use the model for the shape of things; use your senses for the truth of things; and when they part company, believe the sea.

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Sleep well. The watch is quiet and the glass is steady.