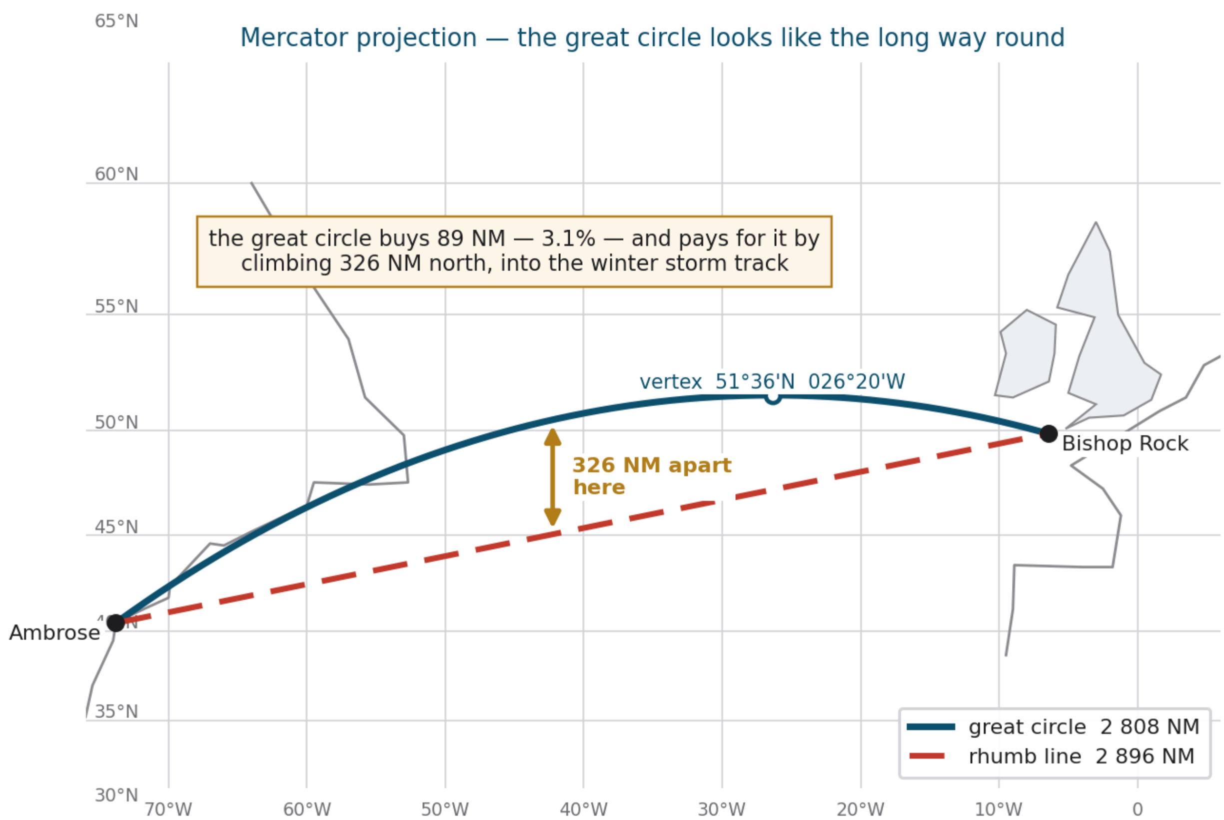
STUDY AID

Passage Planning & Weather Routing

Berth to berth — and the weather in between

Capt. Georgia Hilton



A passage plan is not paperwork. It is the document that says, before you leave, exactly where this ship may go and where she may not — written while you are rested, ashore, and not being shouted at. Weather routing is the half of it that will not hold still: the plan you made on Monday against an ocean that has its own ideas by Thursday. This guide runs the regulation, the chart work, the sailings, the ship's own behaviour in a seaway, and finishes by taking one winter crossing three different ways to see which one gets home first.

Five things to carry out of this guide.

1. The plan runs **berth to berth**, and that includes the water where you will have a pilot. It does not stop at the pilot station.

2. The great circle is the shortest track. It is almost never the shortest *passage*.

3. Distance is not what you are optimising. Time, fuel and damage are — and they do not agree with each other.

4. When the ship starts rolling badly, change course or change speed. Doing nothing is a decision, and it is the wrong one.

5. Nobody can order the master to keep going. That is written into SOLAS on purpose.

SECTION 1

Who owns the plan, and what makes it compulsory

Four separate instruments require a passage plan, and they do not all say the same thing. Know which one says what.

The legal responsibility sits with the master, always. In practice the master hands the work to a navigating officer — conventionally the second mate — who gathers the information, lays the tracks and builds the plan. That delegation changes nothing about who answers for it. **The master approves the plan before the voyage begins**, and the master is the one who explains it afterwards if it goes wrong.

SOLAS Chapter V, Regulation 34 — the one that makes it law

Regulation 34.1 requires that, before proceeding to sea, the master ensures the intended voyage has been planned using appropriate charts and nautical publications, taking into account the guidelines and recommendations developed by the Organization. That last clause is the hinge: it pulls IMO Resolution A.893(21), which would otherwise be advice, into a mandatory instrument.

Regulation 34.2 then says the plan shall identify a route which takes account of ships' routeing systems; ensures sufficient sea room throughout; anticipates all known navigational hazards and adverse weather; and takes account of marine environmental protection measures, avoiding damage to the environment as far as possible.

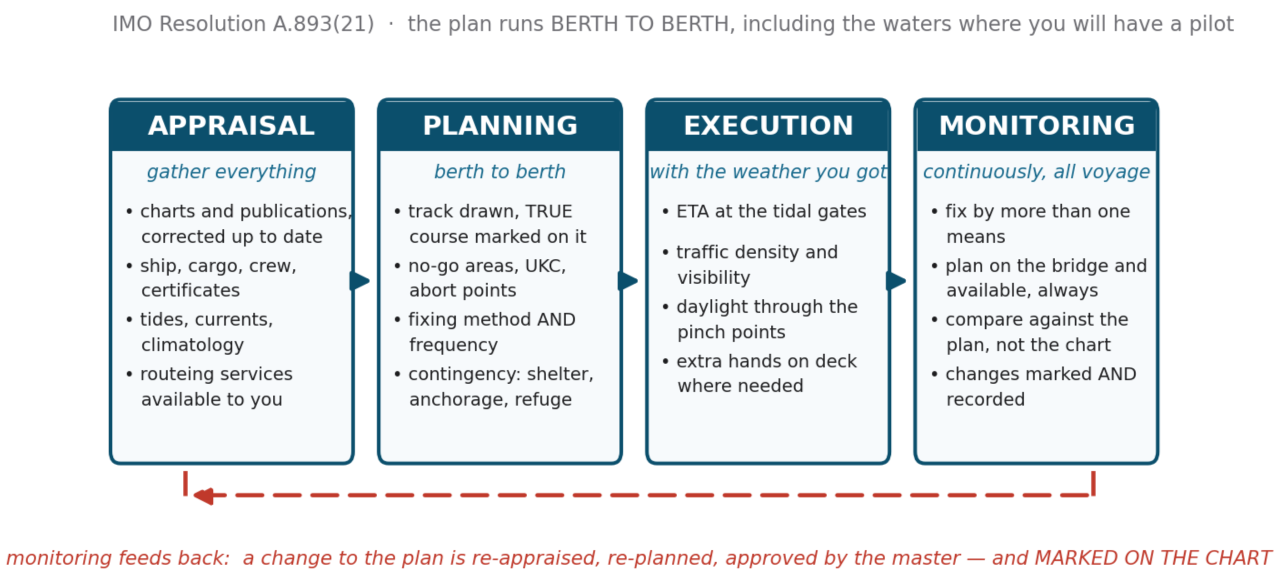
Regulation 34-1 — Master's discretion. Learn this one properly.

Since 1 July 2006 this has been a regulation in its own right, and it is short: the owner, the charterer, the company operating the ship, *or any other person*, shall not prevent or restrict the master from taking or executing any decision which, in the master's professional judgement, is necessary for safety of life at sea and protection of the marine environment.

It exists because ships have been lost with a charterer's voice in the master's ear. If a routing service, an operator or a charterer presses you to hold a track you believe is unsafe, the regulation is on your side and it is worth quoting by number.

IMO Resolution A.893(21) — how to actually do it

Adopted November 1999, the *Guidelines for Voyage Planning* set out the four stages every examiner will ask you to name: **appraisal**, gathering all information relevant to the contemplated voyage; **planning**, in detail, from berth to berth including areas where a pilot will be used; **execution** of the plan; and **monitoring** of the vessel's progress against it.



The four stages. The dashed return is the part that gets forgotten: a change made at sea is not a change until it has been re-appraised, re-planned, approved and marked on the chart.

STCW says something slightly different — and it is examinable

STCW Code Section A-VIII/2, Part 2 is headed *Voyage planning*. It requires the intended voyage to be planned in advance, the course checked before the voyage commences, and the route planned **from the port of departure to the first port of call**. Note the difference: A.893(21) says **berth to berth**; STCW says port of departure to first port of call. Both are correct in their own instrument, and candidates lose marks by blending them.

The US side

Instrument	Who it catches	What it requires
33 CFR 164.80(c)	Towing vessels with a barge or barges, any part of the voyage seaward of the baseline of the territorial sea	Voyage planned before embarking, route checked for hazards, new route planned before any substantial deviation. Nine specific items including Coast Pilot, Light List and Local Notice; weather and visibility; tides, currents and river stages; drafts and air gaps for every bridge; pre-departure checklists; speed and ETA at waypoints; VHF contacts; master's standing orders; and whether the towing vessel has enough power to control the tow
46 CFR 140.635 Subchapter M	Towing vessels under a TSMS or Coast Guard option	A *navigation assessment* by the officer in charge of the navigational watch before getting underway, kept current, communicated to the watch, and recorded
33 CFR 164.11	Vessels navigating underway generally	No voyage-planning requirement at all. It does require position plotting, set and drift, tidal state and safe speed — but do not cite it as the voyage-planning rule, because it is not
ISM Code, section 7	Companies operating under a SMS	Documented procedures for key shipboard operations. The words ‘passage plan’ do not appear anywhere in the ISM Code. Passage planning is treated in practice as one such operation, but the *requirement* comes from SOLAS and STCW

SECTION 2

Appraisal

Gathering everything, before anyone has drawn a line on anything.

Appraisal is the stage crews rush and examiners love. It is not just collecting charts. A.893(21) asks you to look at the ship herself before you look at the ocean.

- **The ship.** Condition, stability, equipment and any operational limitations she carries — a bow thruster out of action or an unreliable gyro changes the plan, not just the defect list.
- **The cargo.** Its special characteristics, especially if hazardous, and its distribution, stowage and securing.
- **The crew.** Competent, and *well rested* — the resolution says so in as many words.
- **Certificates and documents**, in date, for ship, equipment, crew, passengers and cargo.
- **Charts** of appropriate scale, accurate, and corrected up to date.
- **Sailing directions, lists of lights, lists of radio aids.**
- **Routeing guides and passage planning charts** published by competent authorities.
- **Current and tidal atlases, tide tables.**
- **Climatological, hydrographic and oceanographic data** — the pilot charts.
- **Availability of weather routeing services**, including those listed in WMO Publication No. 9, Volume D.
- **Ships' routeing and reporting systems, VTS, and environmental protection measures.**
- **Traffic volume** likely to be encountered.
- **Pilotage information**, including embarkation and disembarkation.
- **Port information**, including shore-based emergency arrangements.

The output of appraisal is not a list. It is an overall assessment that gives a clear indication of all areas of danger, all areas where safe navigation is possible, and any areas where environmental protection measures apply. If you cannot say those three things about the whole passage, you have not finished appraising it.

> **The correction state of the chart is the appraisal.**
>
> A track laid on an uncorrected chart is not a plan, it is a hypothesis. Notices to Mariners, the Local Notice, navigation warnings by NAVTEX and SafetyNET, and — for electronic charts — the update status of every cell along the route.
>
> This is the single most common finding in a port state control inspection of the bridge, and the easiest to avoid.

SECTION 3

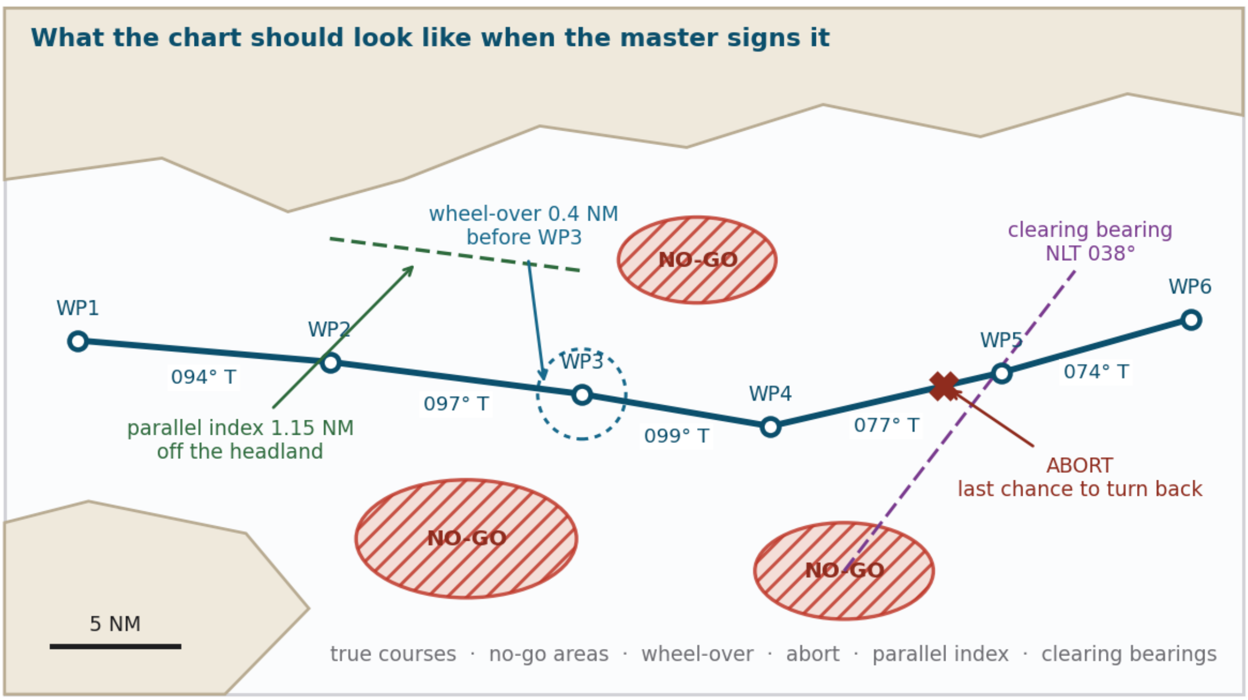
Planning

The stage where you decide, on paper and in daylight, where this ship may go.

A.893(21) requires the plan to cover the entire voyage from berth to berth, including the areas where a pilot will be used. Note what that rules out: you do not stop the plan at the pilot station and hand the ship to a stranger with no track drawn. The pilot is an adviser. The plan is still yours.

What goes on the chart

The resolution asks for the intended route plotted on appropriate scale charts, with the **true direction** of the planned track indicated, and all areas of danger marked. Beyond that bare minimum, this is what good practice actually puts on the sheet:



Everything on this chart is a decision made in advance so that nobody has to make it at three in the morning with a pilot talking and the VHF going.

Mark	What it is	Why it is there
No-go areas	Hatched water the ship physically cannot enter at this draught and this state of tide	Turns a depth judgement into a yes/no. The OOW does not have to do arithmetic under pressure
True course on every leg	Three figures and the letter T	Required by A.893(21). It also stops the compass-error argument before it starts
Wheel-over	The point at which the helm goes over, not the waypoint itself	A ship does not turn at a point. She turns through an advance and a transfer, and if you wait for the waypoint you are already past it
Abort point	The last position from which the ship can still turn round or back out	Past it, the only way is on. Deciding where that is, before you get there, is the whole point
Contingency anchorage / port of refuge	Marked, with its approach	Required as a contingency plan. It also gives the abort decision somewhere to go
Parallel index	The offset distance off a radar-conspicuous object, with its bearing	Continuous cross-track monitoring with no plotting at all. The cheapest safety on the bridge
Clearing bearings and ranges	NLT / NMT a stated bearing on a stated object	A single-glance answer to ‘am I still safe?’
Fixing method and interval	Primary and secondary, written on the plan	Named in A.893(21) 3.2.2.6. Two independent methods, not one method twice
Change of machinery status	Where engines go to manoeuvring, where the second steering motor comes on	Named in the resolution. It is also where the engine room finds out what you want, in advance

Recording it

The details must be clearly marked **and recorded** — on the charts, and in a voyage plan notebook or computer file. Two records, not one. And the plan must be approved by the master before the voyage begins. A plan the master has not signed is a draft.

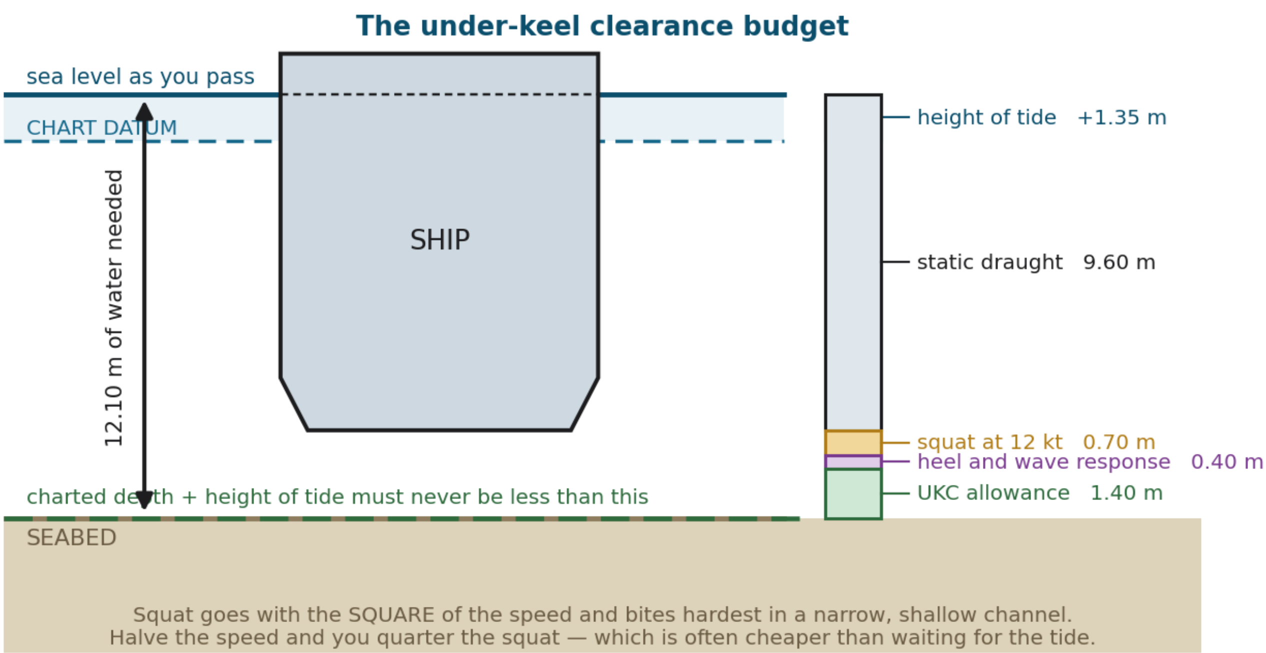
> **Contingency planning is part of the plan, not an afterthought**
>
> A.893(21) 3.2.2.9 requires contingency plans for deep water, port of refuge or safe anchorage. In practice that means, for each stretch of the route: where do I go if the main engine stops here? If visibility closes in here? If I lose steering here?
>
> The answer will often be the same for a hundred miles at a stretch. Write it down anyway. The value is that somebody has thought about it once, calmly, rather than everybody thinking about it at once, badly.

SECTION 4

Under-keel clearance and squat

The one part of the plan where being approximately right is the same as being aground.

A.893(21) 3.2.2.3 requires a minimum under-keel clearance in critical areas. It does not tell you what the number is, because that is the company's and the master's judgement. What it does require is that you have worked it out rather than assumed it.



Every one of these is a real number you can find. Add them up before you sail, not while you are in the channel.

Squat

A ship moving through shallow water pulls herself down and trims. The water has to get past her, it has less room to do it, so it goes faster and its pressure drops — and the ship sits into the hole she has made. Squat grows roughly with the **square of the speed**, and it gets worse as the ratio of water depth to draught falls and worse again in a narrow channel.

The practical consequence is the only bit you need at three in the morning: **halve the speed and you quarter the squat.** If the clearance is marginal, slowing down buys more water than almost anything else you can do, and it is free.

Where the depth actually comes from

Charted depth is measured from chart datum — and which datum depends on whose chart it is. On US charts it is **mean lower low water**; on British Admiralty and most IHO charts it is the **lowest astronomical tide**, which is a lower and therefore safer surface. Know which one you are reading. Either way the water you have is charted depth *plus* the height of tide at the time you pass — which means an error in your ETA is an error in your depth.

And a negative surge is real. A hard northerly in a shallow sea can take half a metre off the predicted height. If the plan only works on the predicted tide, the plan does not work.

SECTION 5

Execution and monitoring

The plan meets the weather, the traffic and the ETA. Something has to give, and it should be a decision rather than a drift.

Execution begins once departure and arrival times are known. A.893(21) asks the master to weigh, among other things: the reliability and condition of the navigational equipment; ETAs at critical points for tide height and tidal flow; meteorological conditions, particularly areas of frequent low visibility, and weather routeing information; whether danger points will be passed in daylight or darkness, and what that does to the accuracy of fixing; and traffic conditions, especially at focal points.

It also asks a question that is easy to skate over: whether any particular circumstance — forecast restricted visibility in an area where position fixing by visual means is critical, for instance — introduces an unacceptable hazard. If it does, the answer is to wait, or to go another way. Not to press on and hope.

Monitoring

The plan must be available on the bridge at all times so the officer of the watch has immediate access to it. Progress is closely and continuously monitored, and any change is made consistently with the guidelines and **clearly marked and recorded**.

- Fix by more than one method. GPS is a method, not a religion. Visual bearings, radar range and bearing, a transit, a line of soundings — any of them will tell you that the GPS is lying long before the GPS does.
- Compare the ship against **the plan**, not just against the chart. Being in safe water is not the same as being where you said you would be.
- A change to the plan is a change to the plan. Mark it, record it, and tell the master. An amended track that exists only in one officer's head is the classic precursor to a grounding.
- Debrief at the end. A.893(21) is silent on this but every good company requires it, and the lessons feed the next appraisal.

SECTION 6

The three sailings

Rhumb line, great circle, composite. What each one costs, and what it buys.

Before any weather comes into it, there is a geometry problem: the earth is round and the chart is flat, so the shortest track and the easiest track are not the same line.

Rhumb line

A rhumb line crosses every meridian at the same angle. It is a straight line on a Mercator chart and a single course to steer from end to end. That is its whole virtue, and it is not a small one — one course, no alterations, nothing to get wrong.

Work it with Mercator sailing. The difference of meridional parts (DMP) does the projection for you:

Rhumb line, Ambrose to Bishop Rock

Ambrose 40°27.0′N 073°50.0′W → Bishop Rock 49°52.5′N 006°26.7′W

d.lat = 9°25.5′ N = **565.5′ N** d.long = 67°23.3′ E = **4 043.3′ E**

DMP = MP(49°52.5′N) – MP(40°27.0′N) = **804.8**

tan Co = d.long / DMP = 4 043.3 / 804.8 = 5.0242 → Co = **N 78.743° E = 078.7° T**

Distance = d.lat / cos Co = 565.5 / cos 78.743° = **2 896.9 NM**

Steer 078.7°, but do not round before that last division. At this course angle the distance moves about 254 NM for every degree of course, so 78.7° gives 2 886 NM and 78.74° gives 2 896.1 — carry three decimals and it comes out right.

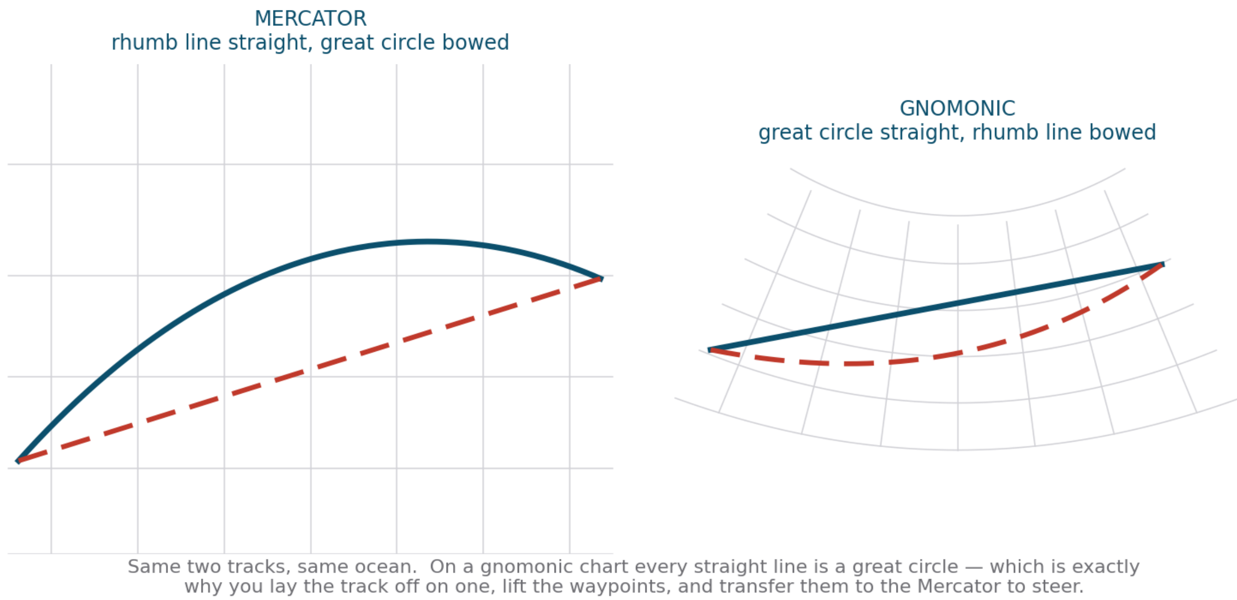
Your tables will not give you 804.8, and that is not an error.

The meridional parts printed in Bowditch and in Norie's are computed on the **spheroid**. The figure above is the **spherical** value, which is what every formula in this guide uses so that everything stays consistent.

From the tables you would get DMP 802.1, a course of 078.8° and a distance of about 2 906 NM — nine miles in two thousand nine hundred, and four hundredths of a degree of course. Neither of those is steerable. Use the tables in the exam, use whichever you like at sea, and do not mix the two inside one calculation.

Great circle

A great circle is the shortest track between two points on a sphere. It is a straight line on a **gnomonic** chart and a curve on a Mercator, and the course changes continuously, so in practice you sail it as a series of rhumb-line legs between waypoints — every five degrees of longitude is the usual convention.



The same two tracks on the two projections. Lay the great circle off on the gnomonic where it is straight, lift the waypoints, and transfer them to the Mercator to steer.

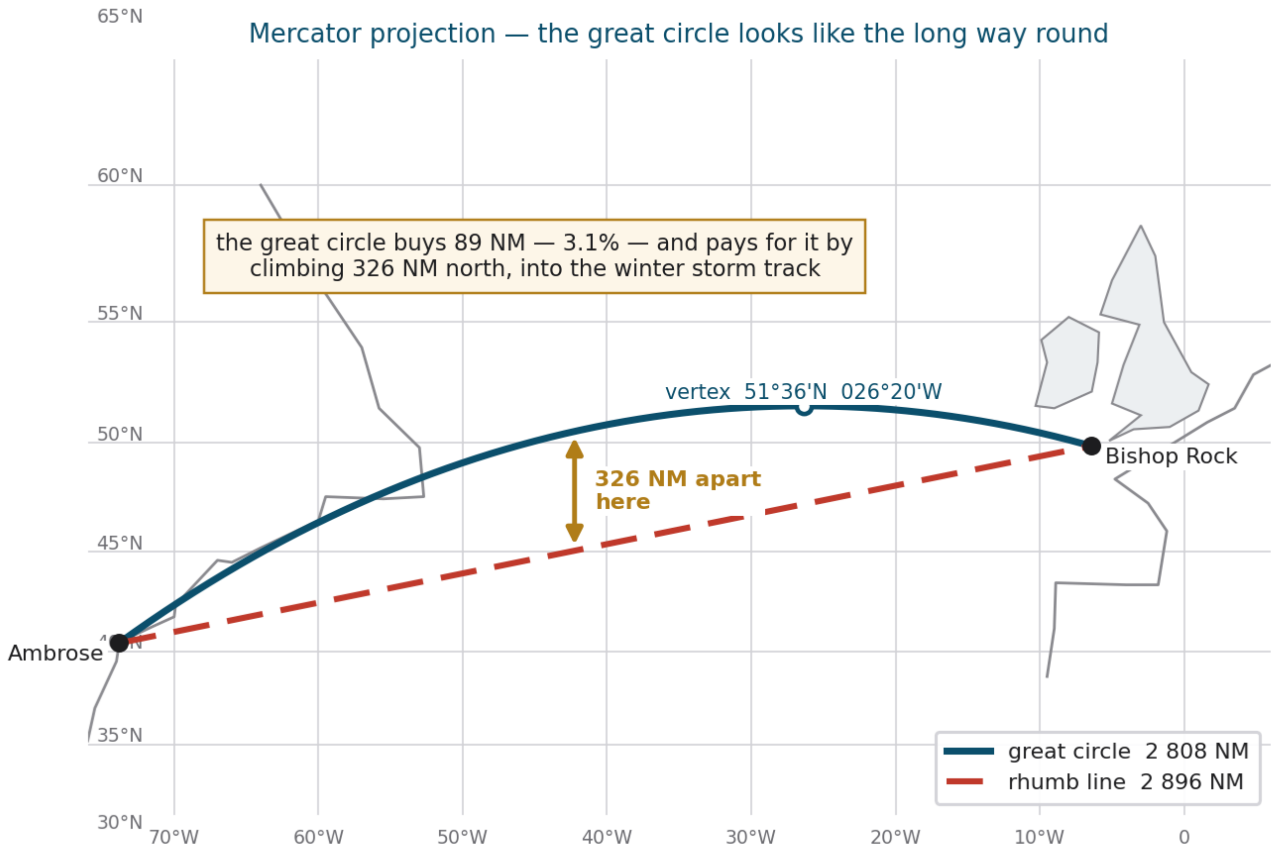
Great circle, same two points

$\cos d = \sin L_1 \sin L_2 + \cos L_1 \cos L_2 \cos(\text{d.long}) \rightarrow d = 46°47.5' =$ **2 807.5 NM**

Initial course **054.7° T** final course **105.5° T** — a swing of nearly 51 degrees across the ocean

Vertex (Clairaut): $\cos L_v = \cos L_1 \sin Co \rightarrow$ 51°36.1′N 026°20.4′W

Saving over the rhumb line: **89.4 NM** — 3.1% of the 2 896.9 you would otherwise steam, and about six hours at 15 knots

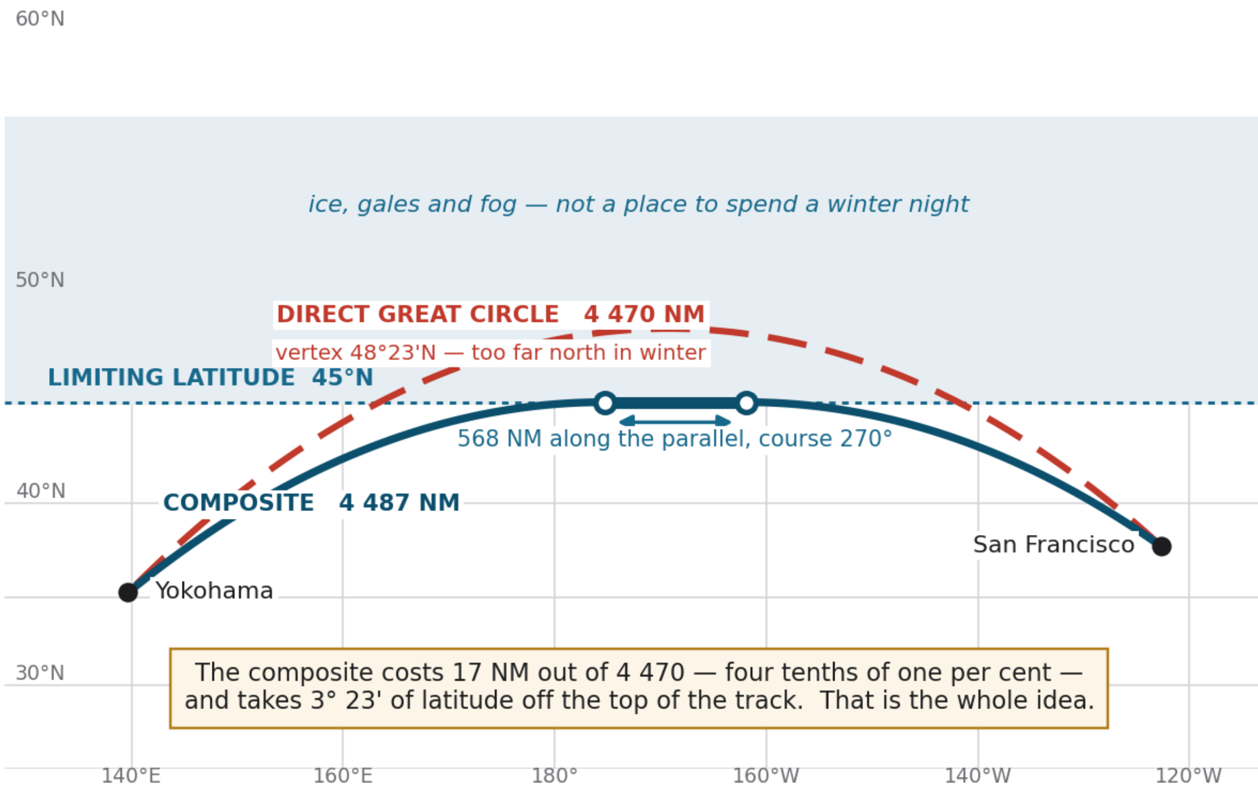


Eighty-nine miles saved. Three hundred and twenty-seven miles further north to save them.

That is the trade the whole of weather routing turns on. The great circle is 3.1% shorter and takes you 326 miles deeper into the North Atlantic winter storm track. In July you take it and think nothing of it. In January you had better have a reason.

Composite great circle

Sometimes the great circle's vertex is somewhere you simply will not go — into the ice, into the Southern Ocean, or north of a limit the company has set. The composite is the answer: a great circle from the departure until it reaches the limiting latitude, a run along that parallel, and a second great circle down to the destination.



San Francisco to Yokohama. Three degrees and twenty-three minutes of latitude, bought for seventeen miles.

Working a composite

For each leg, the vertex sits **on** the limiting latitude, so Clairaut gives you the course directly:

$\sin Co = \cos L_v / \cos L$ where L_v is the limiting latitude

Distance to the vertex: $\cos d = \sin L / \sin L_v$

Longitude of the vertex: $\cos (d.long) = \tan L / \tan L_v$

Then the middle leg is simply distance along a parallel: $d.long \times \cos L_v$

Track	Distance	Highest latitude	Cost
Rhumb line	4 712 NM	37°45′N, at San Francisco	+242 NM on the great circle
Direct great circle	**4 470 NM**	48°23′N	the shortest, and the coldest
Composite, limit 45°N	4 487 NM	45°00′N	**+17 NM — 0.4%**
Composite, limit 42°N	4 531 NM	42°00′N	+61 NM — 1.4%

SECTION 7

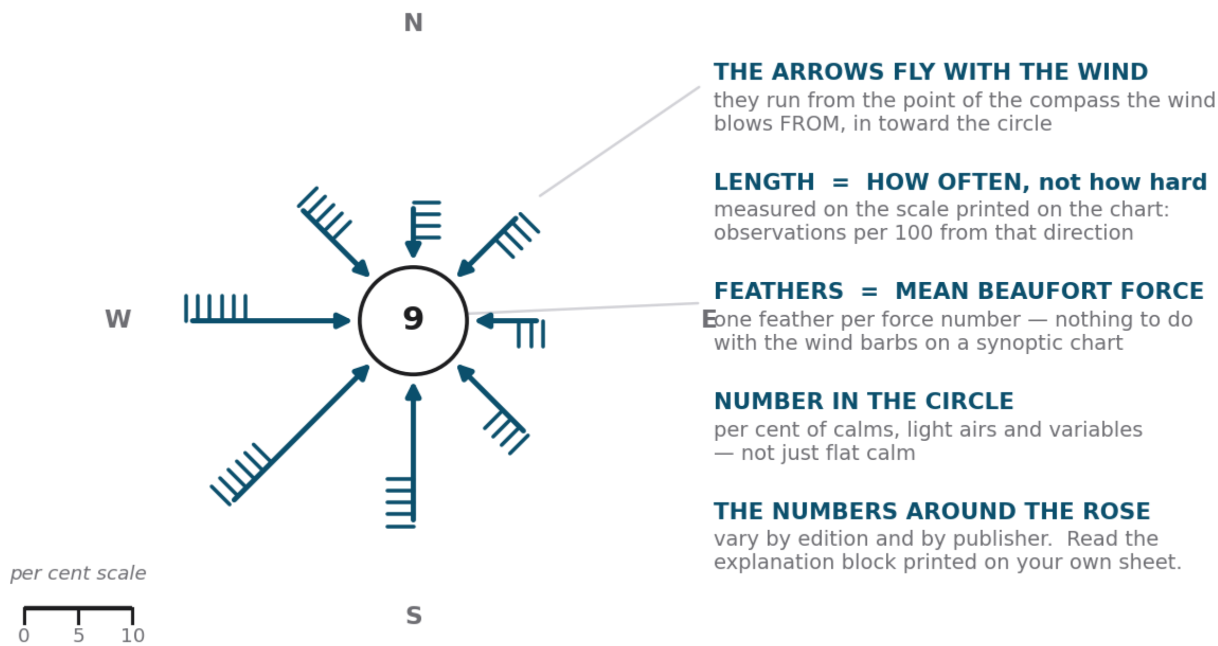
Climatology: the pilot charts

A century of logbooks, one square of ocean, one month at a time.

Before there is a forecast there is a climatology — what this ocean usually does, in this month. That is the pilot chart, published by NGA as the *Atlas of Pilot Charts* in five regional volumes, twelve monthly sheets each, and downloadable free from the NGA Maritime Safety Information site.

A forecast tells you what will happen for four days. A pilot chart tells you what to expect for a month, and it is the right tool for the decision you make before you sail: **which season, and which window inside that season.** No amount of clever routing recovers a passage planned into the wrong month.

The pilot chart wind rose — one square of ocean, one month, a century of logbooks



The densest thing on the sheet. Four elements are standard everywhere; the loose numbers around the outside are not, so read the explanation block printed on your own chart.

The wind rose is not a wind barb. Do not read it like one.

On a synoptic chart, a barb tells you the **speed** of the wind at one instant. On a pilot chart, the length of the arrow tells you **how often** the wind blew from that direction — observations per hundred — and the feathers give the **average Beaufort force**, one feather per force number.

Students who have just learned barbs read the feathers as speed and the length as strength, and get the answer exactly backwards.

One more caution: the numbers printed around a rose are **not** standard across editions and publishers. On some sheets a figure beside a very long arrow is that arrow's own percentage, printed there because the arrow will not fit inside the square. **Read the explanation block printed on the sheet in your hand.** It is on every chart, and it is the only authority that matters.

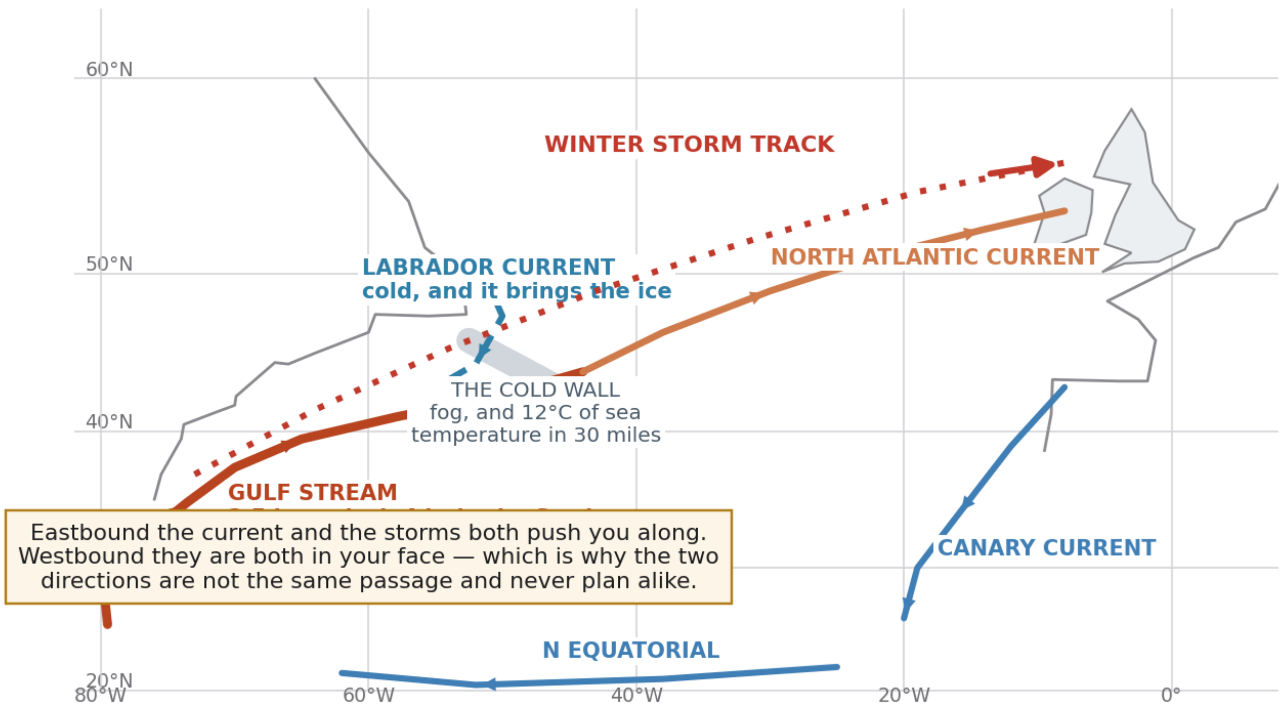
The rest of the sheet carries quarterly average current sets, isobars and isotherms, percentage of days with fog, iceberg and field-ice limits with the date sighted, the tracks of individual storm centres plotted at Greenwich noon with their dates, and lines of equal magnetic variation. It is a remarkable amount of information for one sheet of paper, and it is free.

SECTION 8

Ocean currents

Two and a half knots is a third of a day over a North Atlantic crossing. It is worth planning for.

A fair current of 2.5 knots against a ship making 15 adds a sixth to your speed over the ground. A foul one takes the same away. Over 2 800 miles that is the difference between arriving on a Thursday and arriving on a Friday, and it costs nothing but the planning.



The Gulf Stream, the North Atlantic Current, and the storm track that runs more or less along them. Eastbound all three are with you. Westbound all three are not.

Current	Speed	What it means to you
Gulf Stream, Straits of Florida	up to about 4.5 kt	Off Cape Florida where the channel narrows. Coast Pilot 4 gives a fair allowance of 2.5 kt northerly for a crossing at Jupiter or Fowey Rocks
Gulf Stream, off Hatteras	about 2.5 kt typical	Coast Pilot suggests allowing 1 to 1.5 kt north-easterly for about 40 miles. The axis wanders by tens of miles and throws off eddies that can set you the other way entirely
North Atlantic Current	0.5 to 1 kt	The Stream's continuation, spread wide and slow. Worth having, not worth a detour
Labrador Current	0.5 to 1 kt, cold	Sets south along the Canadian shelf. It carries the ice, and where it meets the Stream you get the cold wall: sea temperature falling 10–12 degrees in thirty miles, and fog with it
Agulhas Current	up to 5 kt	See the warning below. This one has killed ships

The Agulhas — the one place where a current is the hazard

NGA Sailing Directions (Enroute) Pub. 171 carries an explicit warning. Between the latitudes of Great Fish Point and Durnford Point, mainly just seaward of the continental shelf, abnormal waves of 19.8 metres or more have been reported — with a very steep leading face preceded by a very deep trough. The hole in front of the wall is what breaks the ship's back.

The mechanism: a cold front comes through, the wind **backs** from north-east to south-west and blows a gale, and the sea it raises runs north-east directly into an Agulhas Current setting south-west at up to five knots. No encounters have been reported inside the 180-metre curve.

The advice: if a cold front with strong south-westerlies is forecast, keep well clear of the seaward edge of the shelf. And note that the ship steaming **south-west** — meeting the waves head-on — is the one that gets hurt.

SECTION 9

What weather routing actually is

Not avoiding all bad weather. Finding the best route through the weather there is.

The aim of optimised weather routing is not to dodge every gale. It is to find the most efficient route — the one that gets the ship, the crew and the cargo there safely, on time, without damage, and without burning fuel you did not need to burn. Those four things pull in different directions, and the routing problem is deciding which one you are actually optimising.

The three contract types

Type	What is fixed	What the router varies
Fixed speed	A single speed, usually the one named in the charter party	Only the track. Simplest, and the most common
Flexible or variable speed	A speed range	Track and speed together. More room to dodge a system by slowing down and letting it pass ahead
Fixed ETA	The arrival time	Track and speed, within a range, to arrive exactly when required. Often the most fuel-efficient of the three, because there is no reward for arriving early and waiting at anchor

What the router needs from you

- **Weather data** — the higher the resolution and the fresher, the better.
- **The vessel's own profile** — hull, propulsion, design, and above all her speed performance in waves. Generic curves give generic answers.
- **What you actually care about** — a fixed ETA, a maximum acceptable sea state, a cargo that will not take slamming, a deck cargo with a lashing limit. The router cannot infer these.

Shore-side routing advises. It does not command.

A routing service sees a better weather picture than you do and less of your ship than you do. It does not know that number three hatch cover is leaking, or that the pilot ladder is stowed on the weather side, or how she felt last night.

SOLAS V/34-1 exists precisely for the moment those two views disagree. Take the advice seriously, keep the recommendation on file, and if you depart from it, write down why.

SECTION 10

The products you actually use

What comes over the air, when, and what changed this summer.

The NWS Ocean Prediction Center produces the North Atlantic and North Pacific analyses and forecasts a bridge team works from. Surface analyses are valid at 0000, 0600, 1200 and 1800 UTC, with isobars at 4 mb intervals and 24-hour forecast positions of the highs and lows marked on them.

Current as of this printing: the 72 and 96 hour surface forecast charts are suspended.

Public Notification Statement 26-41 suspended OPC's 72-hour and 96-hour *surface* forecast graphics with effect from 1 June 2026. The 72 and 96 hour **wind and wave** graphics continue, produced from the National Digital Forecast Database, and the tropical 72/96 hour surface forecasts from NHC remain on radiofax — the 72-hour ones; there is no 96-hour tropical surface forecast in that list.

The same notice contracted sea state and wind/wave chart coverage to north of 27°N in the Pacific, and north of 27°N and east of 80°W in the Atlantic.

Printed radiofax schedules still list the suspended products, because the current schedule document predates the change. Check the live OPC site before you rely on a schedule.

The suspension is described as temporary. Treat this paragraph as perishable and verify it against ocean.weather.gov before you teach from it.

Route	Station or service	What you get
HF radiofax	NMF Boston — 4235, 6340.5, 9110, 12750 kHz NMG New Orleans — 4317.9, 8503.9, 12789.9, 17146.4 kHz	Surface analyses and forecasts, 500 mb, wind/wave analyses and forecasts, sea ice, and the North American Ice Service chart. Still operating; the Coast Guard has said it will continue these broadcasts
NAVTEX	518 kHz, coverage to about 200 NM	Navigational and meteorological warnings and forecasts. NHC issues Miami, San Juan and New Orleans area forecasts at 0345, 0945, 1545 and 2145 UTC
Inmarsat SafetyNET II Iridium SafetyCast	METAREA IV and XII, four times daily	High seas forecasts and warnings, tropical cyclone bulletins, tsunami warnings. SafetyCast became operational 12 June 2023
FTPMail	by email request	OPC products delivered to a low-bandwidth ship
Internet	ocean.weather.gov	Everything, fastest — and carrying the NWS's own standing caution that the internet is not part of the operational data stream and should never be relied on as the means of obtaining the latest forecast and warning data

Why you look at the 500 mb chart

The surface chart tells you what the weather is. The 500 mb chart tells you whether the surface forecast is likely to verify. It shows the steering flow — the long-wave troughs and ridges that decide where surface lows will go over days two to five. Contours at 60-metre intervals, wind barbs in knots. If the upper pattern is amplified and slow-moving, the surface forecast will hold. If it is flat and fast, it will not.

SECTION 11

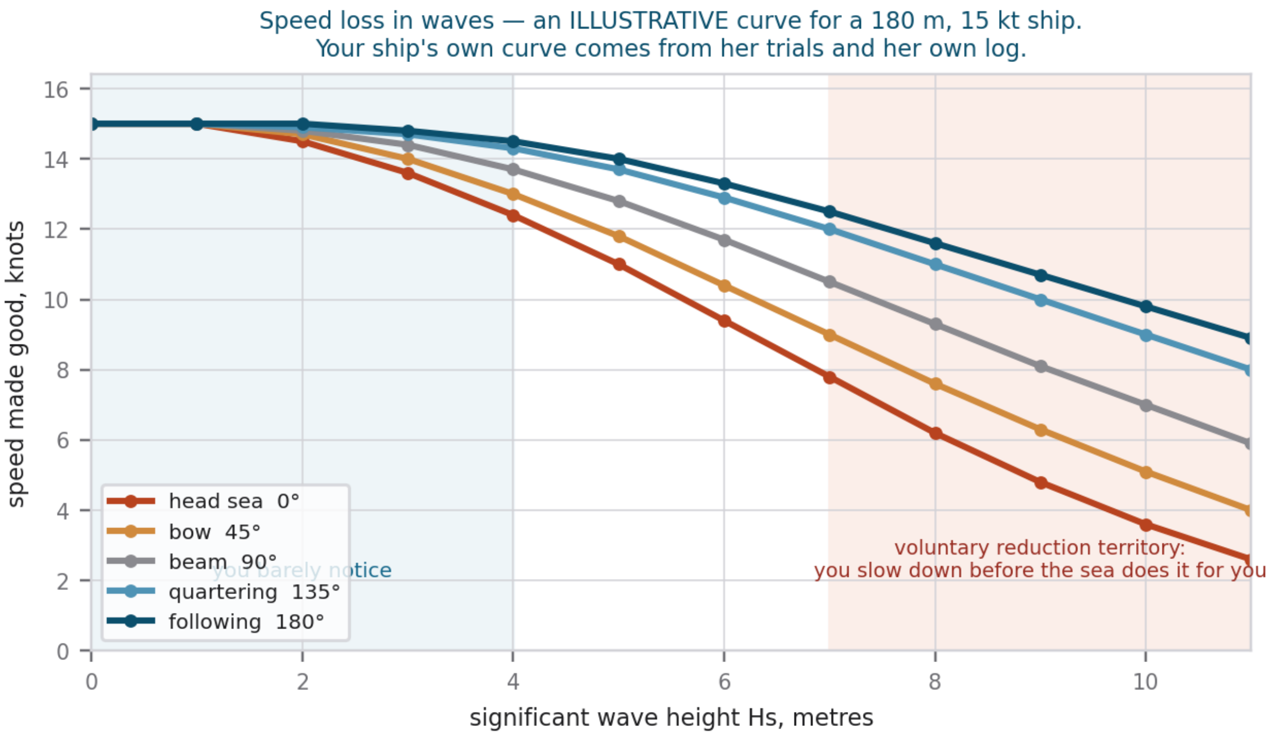
How the ship answers back

The sea does not slow you down evenly, and it does not roll you randomly.

Speed loss, voluntary and involuntary

Two quite different things get called slowing down, and the distinction matters because they cost different amounts.

- **Involuntary speed loss** is the sea taking speed off you. Added resistance from waves, wind on the hull and superstructure, and the propeller racing and losing thrust. The engine is making the same power. You are burning the same fuel per day and covering less ground — so your fuel per mile goes up.
- **Voluntary speed reduction** is you pulling the throttle back to stop the ship hurting herself. Power falls roughly with the cube of speed, so this actually saves fuel per day — it costs you time, not bunkers.



An illustrative curve. Your ship's own comes from her trials and, more honestly, from her deck logs.

Notice the shape. In a following sea the ship keeps most of her speed well into a gale; in a head sea she is down a quarter by Hs 5 metres and a half by Hs 7. That asymmetry is the reason eastbound and westbound crossings of the same ocean are not the same passage.

Encounter period — the number everything else depends on

The period of the sea is a property of the sea. The period at which it arrives at your ship depends on how fast you are going and which way you are heading. That is the encounter period, and it is the number that decides whether you roll comfortably or dangerously.

Deriving it, so you can rebuild it if you forget it

In deep water a wave of period T_w travels at $c = gT_w/2\pi = 1.56\ T_w$ m/s, with a wavelength $\lambda = 1.56\ T_w^2$ metres.

The wave has to travel one wavelength past the ship. The closing speed is $c + V \cos \alpha$, with $\alpha = 0$ for a head sea:

$$\mathbf{T_e = \lambda / (c + V \cos \alpha) = 3\,T_w^2 / (3\,T_w + V \cos \alpha)}$$ seconds, with V in knots

Check it: at V = 0 it gives $T_e = T_w$. In a 10 s sea at 20 knots, head-on it gives 6 s and following it gives 30 s. Same sea, five times the difference.

This is the formula in IMO MSC.1/Circ.1228, and the circular also tells you that you can simply time the pitching with a stopwatch instead.

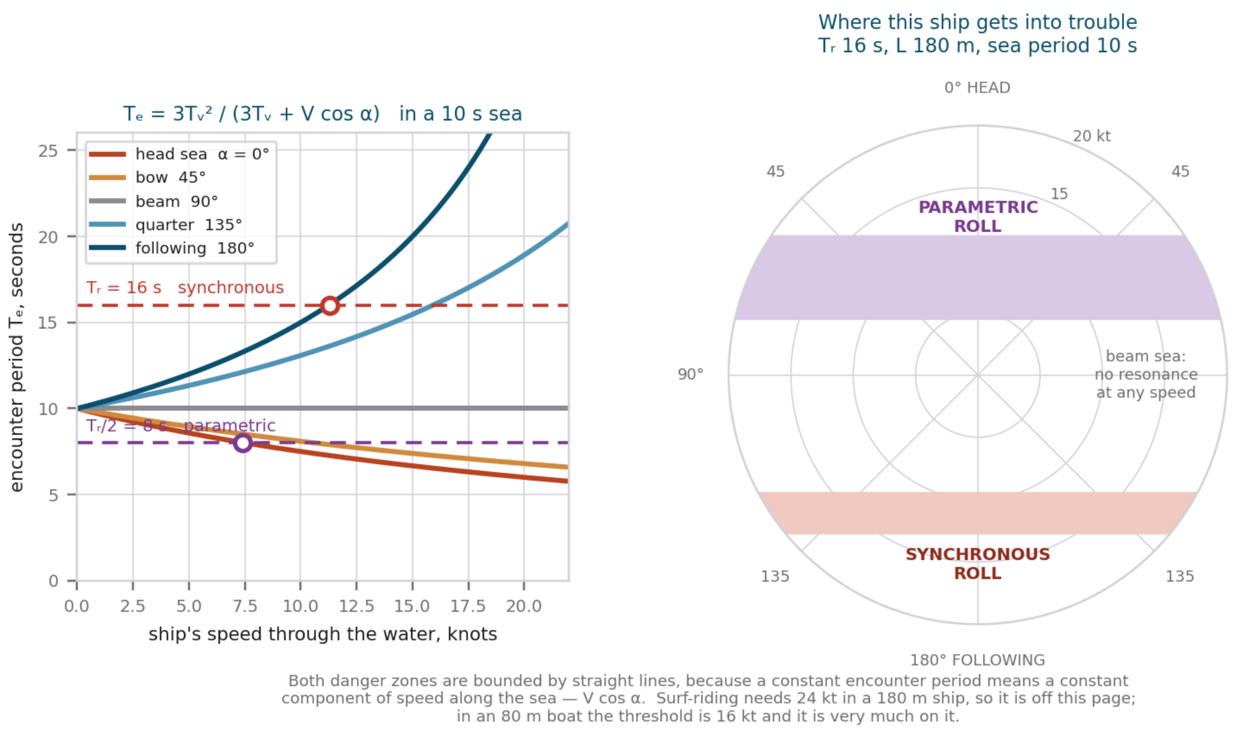
Natural roll period

The ship's own roll period comes from her beam and her stability:

$\mathbf{T_r = 2\,C\,B / \sqrt{GM}}$ with $C = 0.373 + 0.023\,(B/d) - 0.043\,(L/100)$

For a 180 m ship, beam 30 m, draught 11 m: C = 0.358, so a GM of 1.8 m gives T_r = **16.0 s** and a GM of 3.5 m gives T_r = **11.5 s**.

The trap: more GM is not more comfortable. A stiff ship has a short roll period and snaps back hard — that is what throws cargo and people about.



Left: what your speed and heading do to the encounter period. Right: the same information as a place you do not want to be.

The four ways a seaway hurts you

Phenomenon	When	What to do
Synchronous rolling	T_e nearly equals T_r. Every wave arrives in step with the roll and feeds it	Change course, change speed, or both. A tender ship finds resonance in a following sea; a stiff ship finds it in a head sea
Parametric rolling	Wavelength near the ship's length, in head or following seas, and the waterplane — so the GM — changing as she pitches. MSC.1/Circ.1228 gives **two** encounter ratios: 1:0.5, where T_e is about half T_r and the rolling is symmetric and large; and 1:1, where T_e is about equal to T_r and the rolling is asymmetric	Rolls build from nothing to dangerous in a few cycles, on a heading that felt fine. Alter course out of the head sea and change speed
Surf-riding and broaching	Following and quartering seas, $135° < \alpha < 225°$, and speed above $1.8\sqrt{L} / \cos(180° - \alpha)$ knots, L in metres	A 180 m ship needs 24 kt in a following sea to be at risk — most cannot. An 80 m boat needs only 16. This is a small-vessel and a fast-vessel problem
Successive high wave attack	Mean wavelength greater than 0.8 L, Hs greater than 0.04 L, and T_e roughly 1.8 to 3.0 times the wave period	For a 180 m ship: waves longer than 144 m and Hs above 7.2 m. Change course or speed to break the group encounter

Reduced stability on a wave crest

When a wave crest sits amidships, the ends of the ship are in the troughs, the waterplane narrows, and GM falls — briefly, but when you need it. MSC.1/Circ.1228 puts the critical band at wavelengths from **0.6 L to 2.3 L**, and within that band the loss of stability is roughly proportional to wave height.

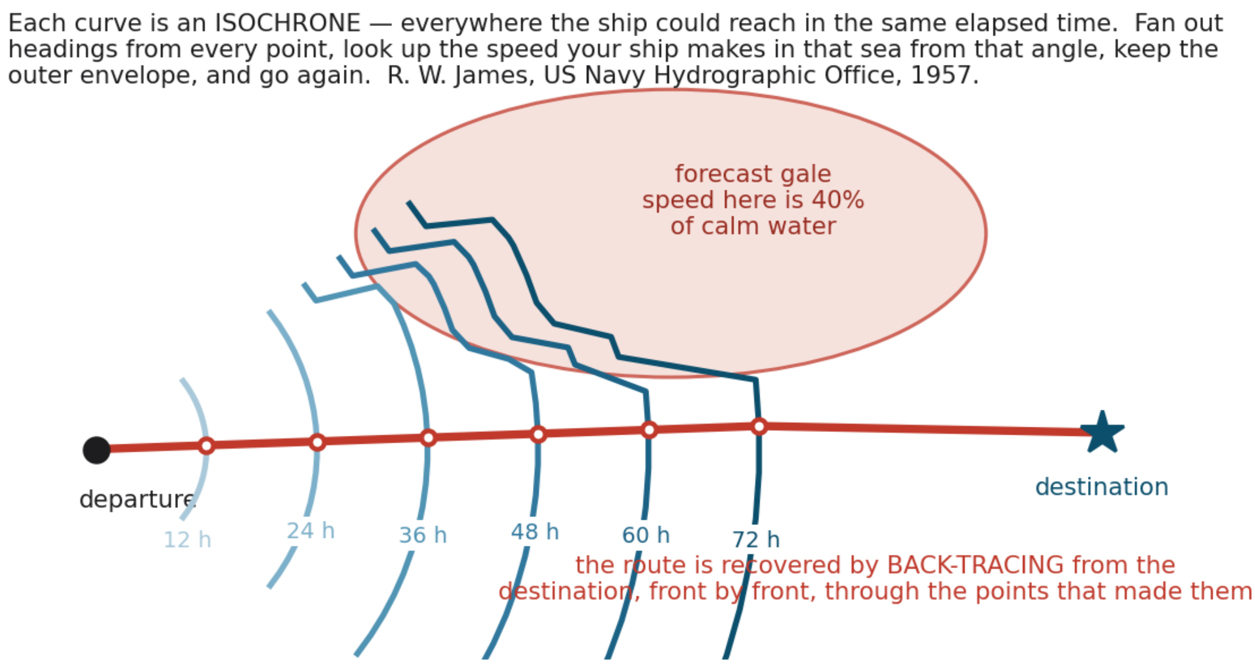
For a 180 m ship that is wavelengths from 108 m to 414 m, which corresponds to sea periods of roughly 8.3 to 16.3 seconds — in other words, most of an ordinary gale.

SECTION 12

The isochrone method

What the routing software is doing while it thinks.

R. W. James published the method for the US Navy Hydrographic Office in 1957, and every modern router is a descendant of it. The idea is simple enough to draw by hand, which is the best reason to learn it: it stops the software being magic.



Six twelve-hour steps. Where the gale bites, the isochrone develops a notch, and the optimum route runs round the outside of it.

- An **isochrone** is the locus of every point the ship could reach from where she is in a given elapsed time. Not where she will go — where she *could*.
- From the departure position, fan out a set of candidate headings. For each one, look up the speed the ship makes in the forecast sea for that wave height and that relative angle, and advance her one time step.
- Join the outermost of the resulting points. That curve is the first isochrone.
- Now do it again from every point on that curve, using the forecast valid for the next time step — and again, until an isochrone reaches the destination.
- Recover the route by **back-tracing**: from the destination, step back through the stored parent points, front by front, to the departure.

Modern operational routers mostly do not use plain isochrones any more. They run Dijkstra or A* over a grid, or dynamic programming that optimises track and speed together, or three-dimensional variants that treat time as a search dimension. The change is one of machinery, not of principle: they are all still finding the cheapest path through a field that is changing while you cross it.

What the router cannot know

It has your ship's performance curve, not your ship. It does not know how she is loaded today, what the lashings are like, or that she took a bad one last night and the crew are tired.

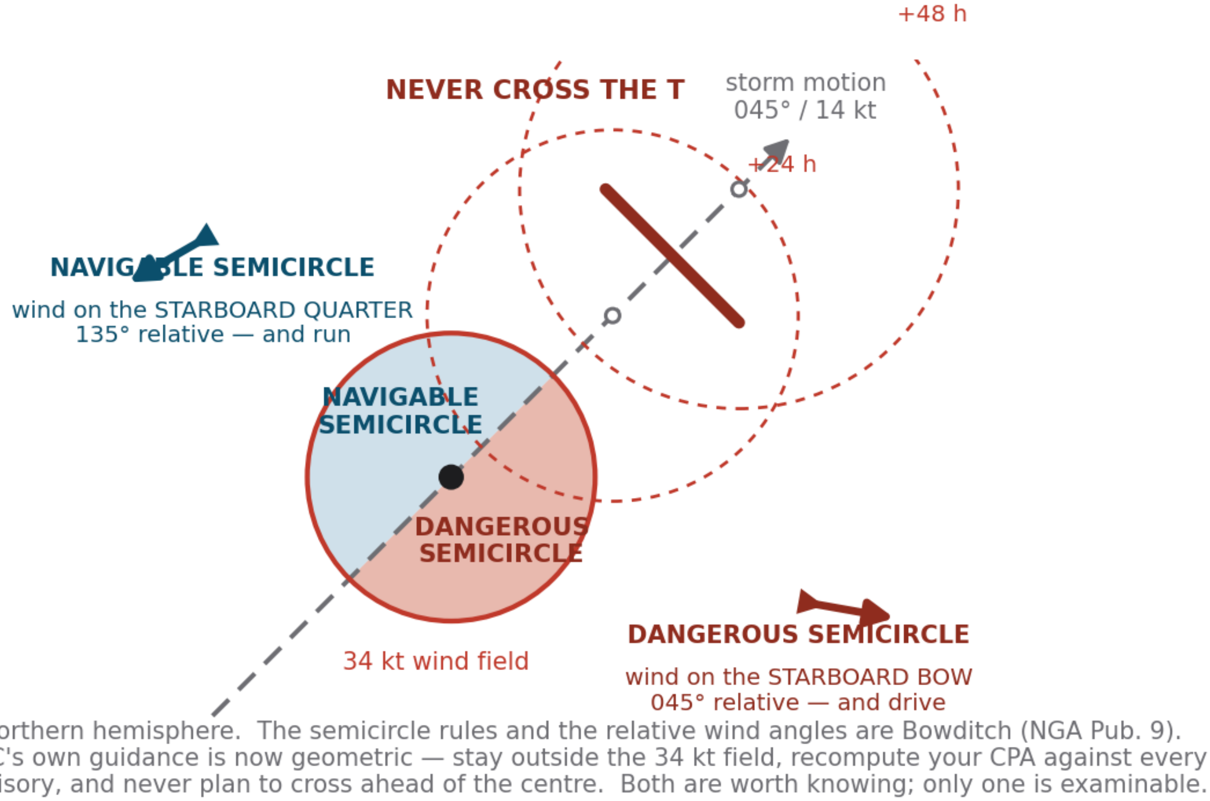
It optimises the objective you gave it. If you asked for minimum time it will give you minimum time, and it will happily route you through a sea state you would never willingly enter, because nobody told it not to.

SECTION 13

Tropical revolving storms

The one weather system you do not route through. You route around it, with room.

Everything else in this guide is about optimising. This section is not. A tropical cyclone is avoided, and the only question is by how much.



Two doctrines, both current, from two different authorities. Know which is which.

The 34-knot rule

NHC's guidance is blunt: for vessels at sea, avoiding the 34-knot wind field is paramount, because as the wind reaches that speed the sea state develops to the point where the ship's ability to manoeuvre falls away rapidly. Every ship in the vicinity should make every effort to remain clear of the maximum radius of analysed or forecast 34-knot winds.

And: **never plan to cross the track of a hurricane.** Storms accelerate without warning, and a plan that depends on getting across in front of one is a plan that depends on the forecast being right.

The 1-2-3 rule — teach it, but teach that it was retired.

The rule adds 100, 200 and 300 nautical miles to the **34-knot wind radius** at the 24, 48 and 72 hour forecast positions. Note what the radii are added to: the 34-knot radius, not the forecast centre. The numbers came from a 10-year average track error of roughly 100 NM per day of forecast.

NHC discontinued it in 2016 and replaced it with the Tropical Cyclone Danger Graphic, built from 34-knot wind speed probability contours — the 5% and 50% contours out to 72 hours. The stated reason was that track forecasting had improved by more than 60% since the 1980s and the 1-2-3 rule was over-warning: drawing danger areas so large that mariners stopped believing them.

The 2025 Atlantic verification bears that out. Mean official track error was **32.6 NM at 24 hours, 53.4 NM at 48, and 85.2 NM at 72** — against allowances of 100, 200 and 300.

Be aware that NHC's own *prepare/marine* web page still describes the 1-2-3 rule with no disclaimer, while the 2023 Mariner's Guide says it is no longer endorsed. Both pages are live. For an exam, know the rule and know it was withdrawn; at sea, use the probability graphic and keep the rule as a conservative back-of-the-envelope when you have nothing else.

The cone of uncertainty

The cone is formed by enclosing the area swept by circles along the forecast track, each sized so that **two thirds** of historical official forecast errors over a five-year sample fall inside it. Separately, historical data indicate the entire five-day path of the centre stays within the whole cone about **60 to 70%** of the time. Those are two different numbers about two different things, and they are routinely confused.

The cone describes the centre. Nothing else.

It says nothing whatever about how far out the dangerous winds and seas extend — and they routinely lie well outside it. A ship comfortably outside the cone can still be inside a 34-knot field. Plot the wind radii, not the cone.

The semicircles

This is Bowditch — NGA Pub. 9 — rather than NHC, and it is what US licence examinations ask for. Facing the direction the storm is moving, in the northern hemisphere:

Where you are	Why	What you do
Right of the track the dangerous semicircle	The rotational wind and the storm's forward motion add together, so the wind is stronger; and the wind and sea set you into the storm's path	Bring the wind on the **starboard bow, 045° relative**, hold course and make as much way as possible
Left of the track the navigable, or less dangerous, semicircle	The forward motion subtracts from the rotational wind, and the wind blows you away from the track	Bring the wind on the **starboard quarter, 135° relative**, hold course and make as much way as possible
On the track, ahead of the centre	The worst place to be, and the easiest to end up in by doing nothing	Bring the wind about **160° relative** — two points on the starboard quarter — and run, to put yourself in the navigable semicircle. Then follow that rule

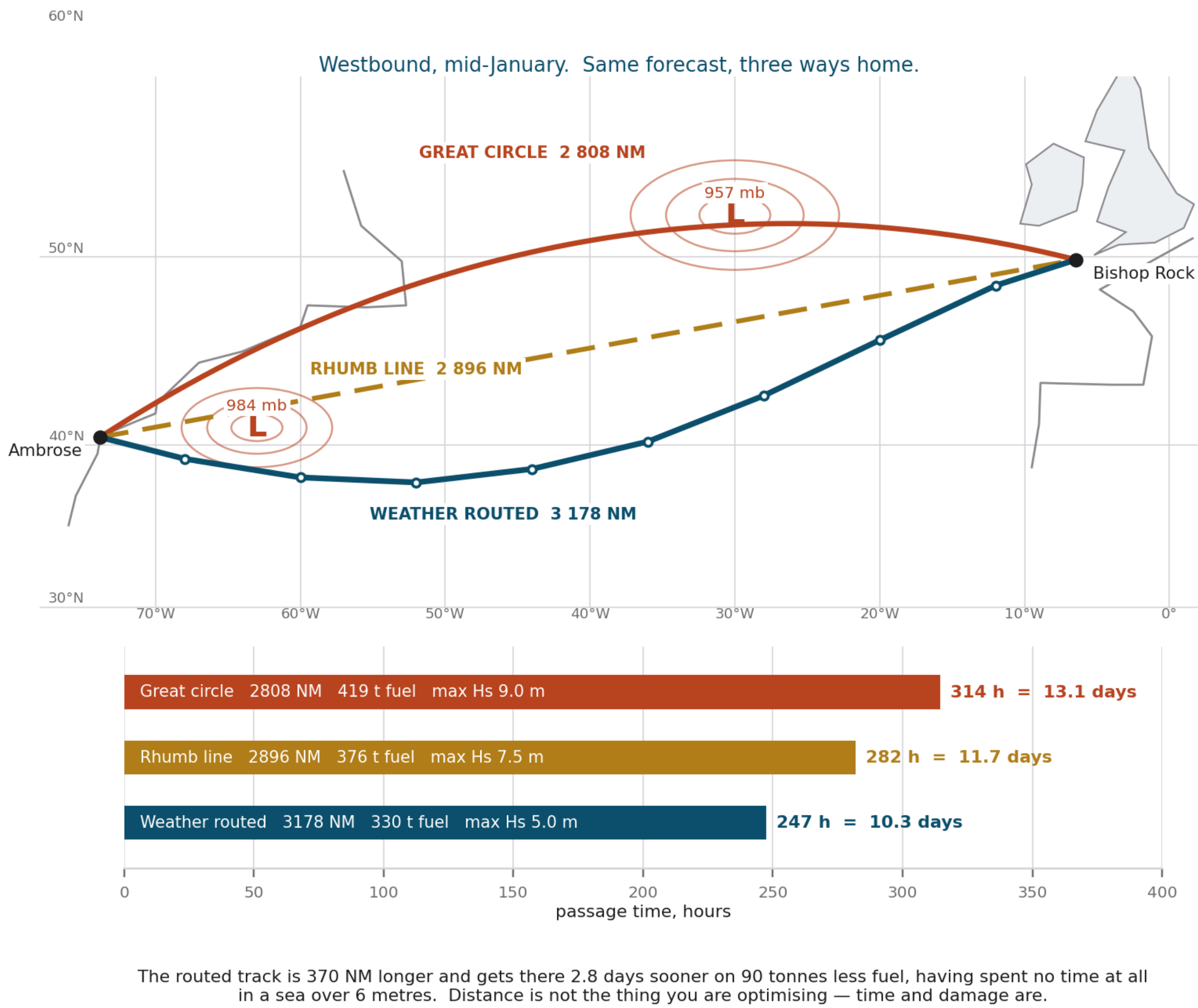
In the southern hemisphere it all mirrors: the dangerous semicircle is the **left**, and the wind goes on the port bow at 315° relative, or the port quarter at 225° relative, or about 200° relative if you are in the path.

SECTION 14

A crossing worked three ways

Westbound, Bishop Rock to Ambrose, mid-January. Same ship, same forecast, three tracks.

Everything up to here has been a piece of the argument. This is the argument. One 180-metre ship, 15.0 knots in calm water, 32 tonnes a day at full power. One winter forecast: a 957 mb low near 52°N 030°W, and a second developing off Hatteras. Three ways home.



The shortest track is the slowest passage, by nearly three days.

How to read the arithmetic

For each leg: take the forecast significant wave height and the angle the sea makes with your course, read the speed off the performance curve, and divide the leg distance by it to get the hours. Add them up.

That is all a routing computer does, in more places and faster. Doing it by hand once is what makes the output believable.

Leg	NM	Hs	rel	kt	h	what is happening
Bishop Rock – 12W	218	4.5	30	12.2	17.9	south-westerly swell ahead of the warm front
12W – 20W	305	6.5	20	9.1	33.6	warm front, sea rising fast
20W – 28W	299	9.0	10	5.1	58.2	**957 mb centre 120 NM north — the worst of it**
28W – 36W	300	8.5	25	6.3	47.6	still in the western semicircle
36W – 44W	309	7.0	30	8.6	35.9	cold front through, sea easing
44W – 52W	326	5.5	35	10.9	29.9	ridge between the two systems
52W – 60W	351	6.0	25	10.0	35.3	the second low, off Hatteras
60W – 68W	389	5.0	40	11.7	33.2	sea easing, wind backing
68W – Ambrose	311	3.5	50	13.6	22.9	
GREAT CIRCLE TOTAL	**2 808**			**8.9**	**314.5**	**13.1 days at sea · 419 tonnes**

Every speed in that table came off the performance curve — there are no fudges in it. Do the same for the other two tracks and you get:

Track	Distance	Passage	SOA	Fuel	Max Hs	h > 6 m
Great circle	2 808 NM	314.5 h 13.1 d	8.9 kt	419 t	9.0 m	175
Rhumb line	2 896 NM	281.8 h 11.7 d	10.3 kt	376 t	7.5 m	87
Weather routed	**3 178 NM**	**247.4 h 10.3 d**	**12.9 kt**	**330 t**	**5.0 m**	**0**

The routed track is **370 miles longer** and gets in **2.8 days sooner**, on **90 tonnes less fuel**, having never seen a sea over 5 metres. It wins on every column at once, which does not always happen — but it wins for a reason that always applies: the great circle spends 175 hours in seas above 6 metres and the routed track spends none.

The fuel column here simply follows the time column, because every leg in this table is run at full power. That is what **involuntary** speed loss means — the engine is doing the same work and the sea is taking the ground. Add a **voluntary** reduction and the two columns come apart: hold four knots through the sixty miles at the centre instead of the 5.1 the sea would allow, and you add **3.3 hours** to the passage and burn **about two fifths less fuel** over that stretch.

Why two fifths and not half

The burn *rate* goes as the cube of speed, so at four knots instead of 5.1 the engine is using $(4/5.1)^3 = 0.47$ — a bit under half — of the fuel per day.

But you are down there for longer, in proportion to 1/V. Over a **fixed distance** the two effects combine and the fuel goes as the **square** of speed: $(4/5.1)^2 = 0.61$, so you save about 39% of the fuel for that stretch, not 53%.

Time and bunkers are different currencies, and the throttle is the exchange rate — but make sure you know which of the two the question is asking about.

This is a deliberately severe case. Do not oversell routing.

A three-day saving comes from one ship meeting one bad storm on one track. Typical routed savings on a North Atlantic crossing are a few per cent of passage time, not a quarter of it.

The honest case for weather routing is not that it makes every passage faster on average. It is that it takes the tail off — it removes the crossings that go badly wrong. That is worth paying for even in the many voyages where it saves you almost nothing.

And a note on the numbers above: the speed-loss curve is illustrative, not any particular ship's, and the forecast is a constructed scenario. The arithmetic is exact; the inputs are teaching inputs. Use your own ship's curve for anything real.

SECTION 15

The tear-out card

Everything in this guide that you would actually want on the chart table.

THE FOUR STAGES — A.893(21)

Appraise — gather everything, including the state of the ship, the cargo and the crew. Output: where is dangerous, where is safe, where the environment is protected.
Plan — berth to berth, including pilotage waters. True courses, no-go areas, UKC, wheel-over, abort, fixing method and interval, contingencies. Marked AND recorded. Master approves before sailing.
Execute — with the tide, traffic, visibility and weather you actually have. Extra hands where needed.
Monitor — continuously, by more than one means, against the plan. Any change is marked and recorded.

THE SAILINGS

Rhumb line: $\tan Co = d.long / DMP$ $\quad dist = d.lat / \cos Co$

Great circle: $\cos d = \sin L_1 \sin L_2 + \cos L_1 \cos L_2 \cos d.long$

Vertex (Clairaut): $\cos L_v = \cos L \times \sin Co$ — and this holds at every point on the track, not just at the start

Composite: $\sin Co = \cos L_v / \cos L$ $\quad \cos d = \sin L / \sin L_v$ $\quad \cos d.long = \tan L / \tan L_v$

Along a parallel: distance = d.long × cos L

THE SHIP IN A SEAWAY

Wave speed $c = 1.56\, T_w$ m/s wavelength $\lambda = 1.56\, T_w^2$ m

Encounter period $\mathbf{T_e = 3\, T_w^2 / (3\, T_w + V \cos \alpha)}$ seconds, V in knots, $\alpha = 0$ head sea

Roll period $\mathbf{T_r = 2\, C\, B / \sqrt{GM}}$ $C = 0.373 + 0.023(B/d) - 0.043(L/100)$

Synchronous roll: $T_e \approx T_r$

Parametric roll: $\lambda \approx L$, and either $T_e \approx T_r/2$ (symmetric, large) or $T_e \approx T_r$ (asymmetric)

Surf-riding: $135° < \alpha < 225°$ and $V > 1.8\sqrt{L} / \cos(180° - \alpha)$ knots, L in metres

Successive high waves: $\lambda > 0.8\, L$ and $Hs > 0.04\, L$

Stability loss on the crest: $0.6\, L < \lambda < 2.3\, L$

The cure for all of them is the same: change course, change speed, or both.

TROPICAL REVOLVING STORMS

Stay outside the **34-knot** wind field. Never plan to cross the track.

Dangerous semicircle (NH, right of the track): wind on the **starboard bow, 045° relative**.

Navigable semicircle (NH, left): wind on the **starboard quarter, 135° relative**.

In the path: wind about **160° relative** and run into the navigable semicircle.

Southern hemisphere mirrors: port bow 315°, port quarter 225°, in the path about 200°.

1-2-3 rule: +100/200/300 NM on the **34-kt radius** at 24/48/72 h — withdrawn by NHC in 2016, still examinable.

THE ARGUMENT, IN ONE LINE

The great circle is the shortest track. The best passage is the one where nothing on board breaks and nobody has to stop.

Passage Planning & Weather Routing · Capt. Georgia Hilton · captaingeorgia.com · free to use for study