

Weather routing – speed or comfort?

or . . . Intuition or witchcraft

or . . . Come with me down the rabbit hole

or . . . This computer stuff is for the ‘young people’

FSC Topic Night (Mark Wheeler & Bill Henson)

April 2023

Agenda

the **'theory'** bit

- **Introduction**
 - Down the rabbit hole
- **Key concepts**
 - Navigation V routing
 - Essentials theory
 - Routing essentials
 - GRIB precision/accuracy/resolution
 - Routing principles – grid versus isochrone, iterative solution, sensitivity
 - Sensitivity
 - Instrumentation – law of diminishing returns
 - Summary

the **'practical'** bit

- **PredictWind** – example
- **Expedition**
 - Quick tour – setup for simplicity, magnetic, etc
 - Course
 - Polar – where you can get them, how you use them & 'modifiers'
 - GRIB – where you get them, how you use them & 'modifiers'
 - Routing setup
 - Review & analysis
- **Summary**
- **Q&A**

The GFS model looks much faster than everything else. Let's go with that.



Should we ignore ECM, ACCESS and MetEye, or is this more of a one-time thing?



It's called 'intuition'.

It's a slippery slope to witchcraft if you ask me.



So are you ready to go down this rabbit hole?



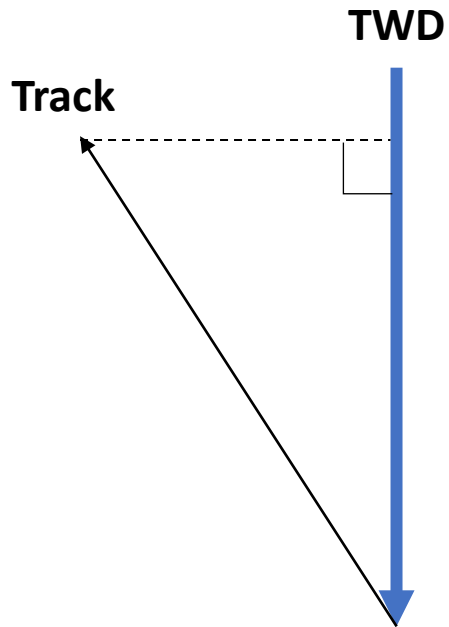
Navigation versus routing *- they are not the same*

Theory

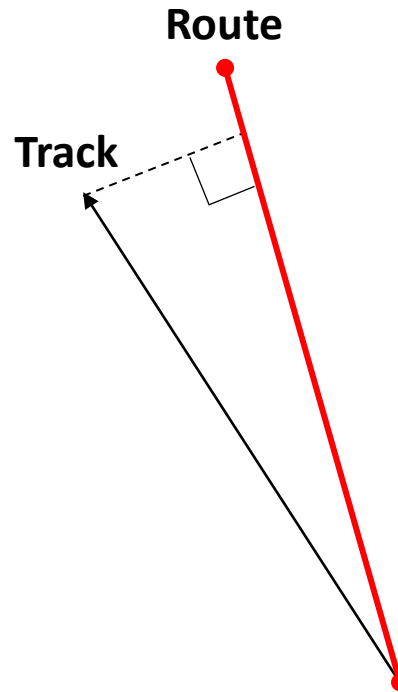
- **Routing** is identifying an optimal track
whereas
- **Navigation** is finding a safe track

Some essential theory - VMG, VMC & XTE

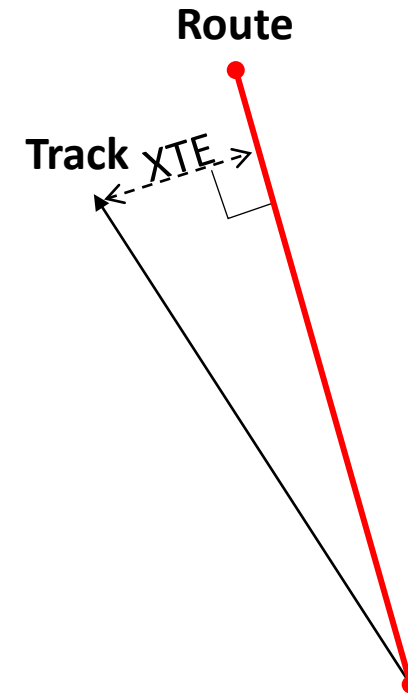
Theory



VMG – the component of boat speed directly towards (upwind) or away (downwind) from the wind



VMC – the component of boat speed directly towards a mark



XTE (cross track error) – the distance you strayed from the route

Routing principles

- how is a route calculated?

Theory

- **Routing** – a numerical procedure to minimize the time to sail a leg through a designated weather system
- **Grid or Isochronal:**
 - Grid (GRIB based) – divides the route area into a grid
 - Isochrone (Polar based)– pushes an isochrone out from the start
- **Resolution** is defined by:
 - Grid – grid size
 - Isochrone – time step

Routing essentials

- need 3 things for routing

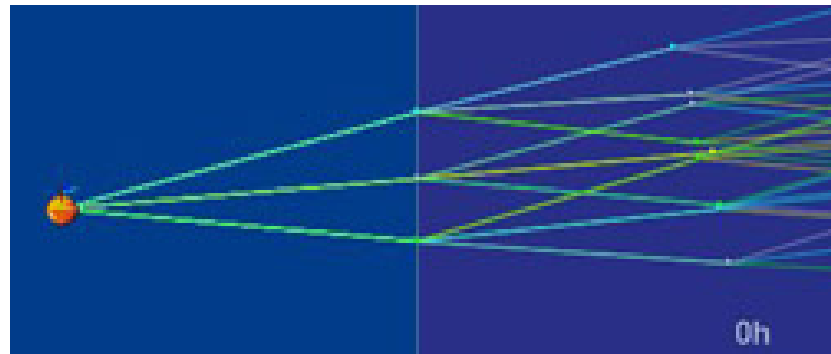
Theory

You need three things:

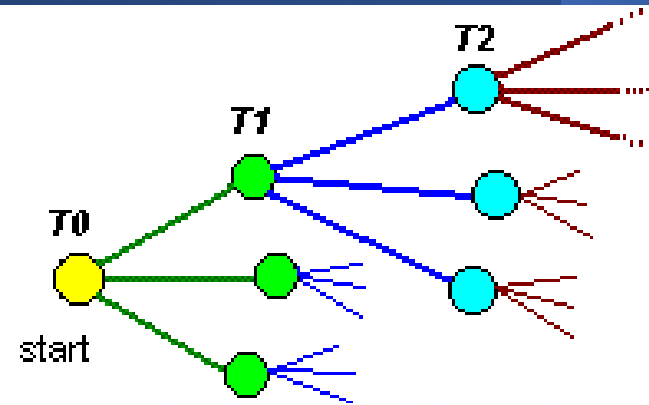
- **Course** – (*.dat or *.gpx file) at least a start and a finish (and often some intermediate points)
- **Polar** – (*.txt file) boat speed performance versus TWS & TWA
- **GRIB** – (grid based binary data file) a collection of self-contained metrological records of 2D data (typically 1 to 200km square grid)

Routing principles - *isochronal*

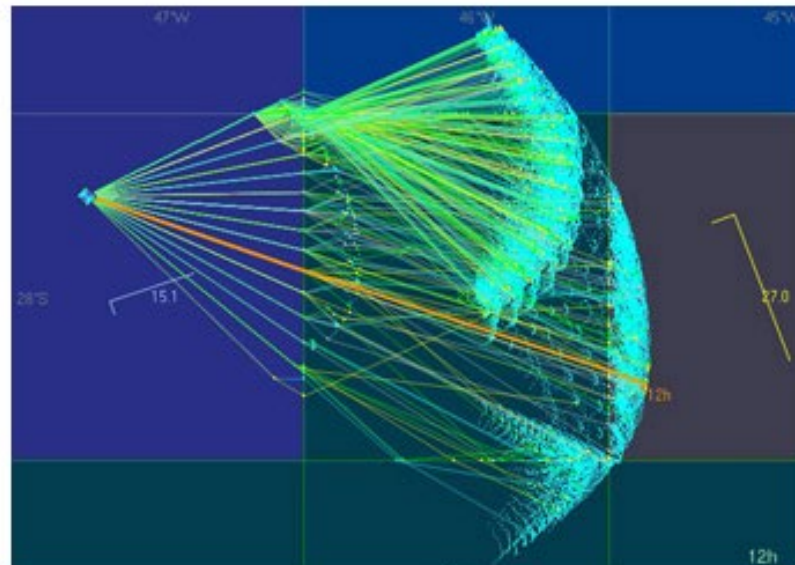
Theory



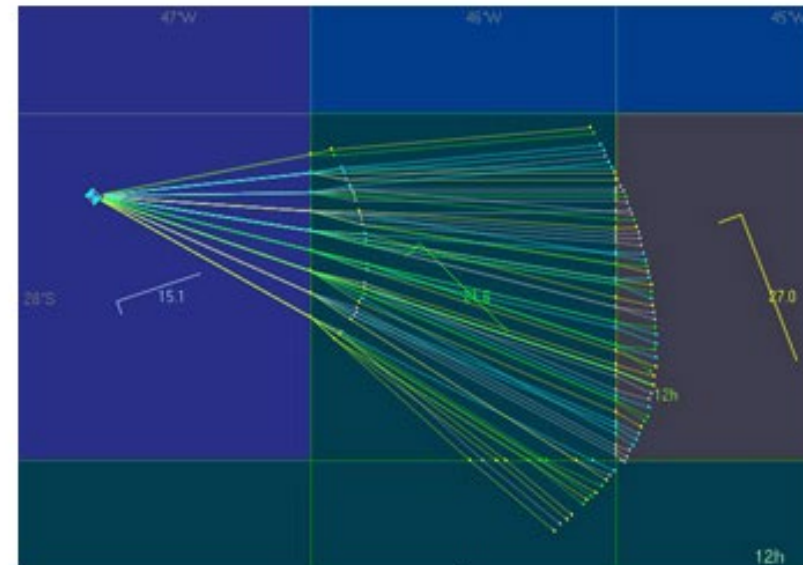
track tree (3 branches)



destination



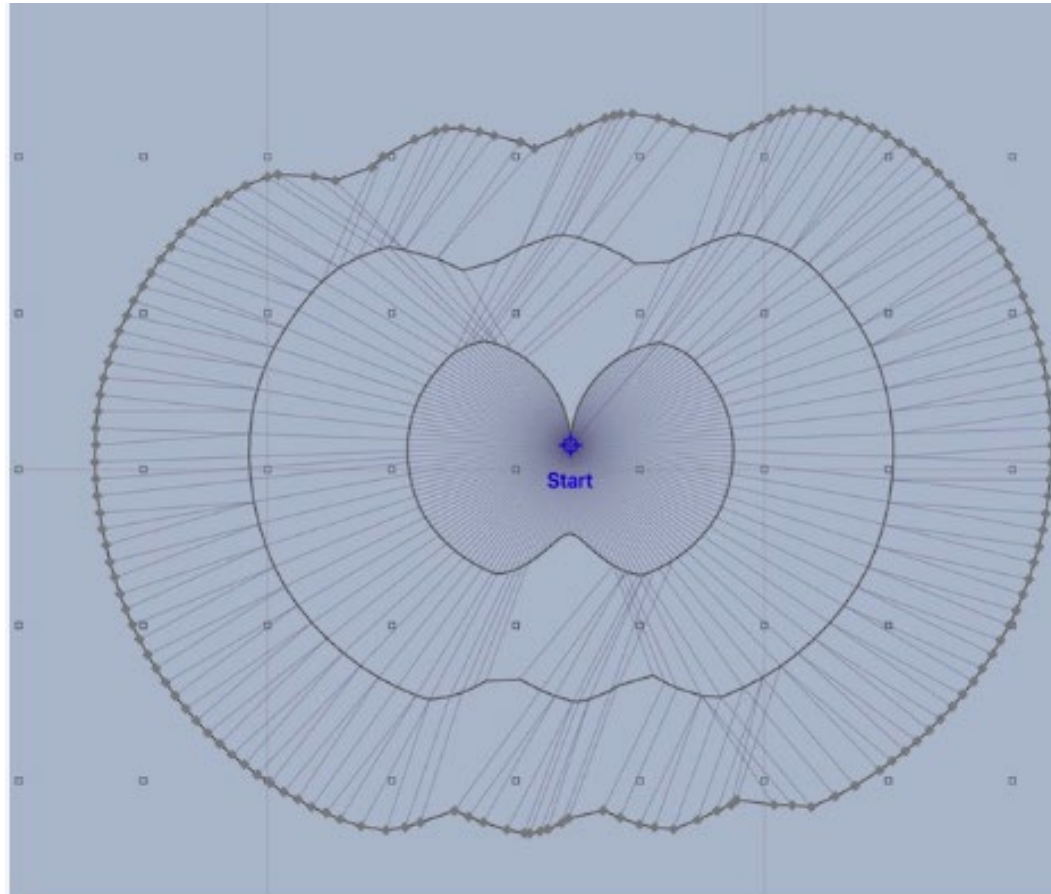
unpruned tree



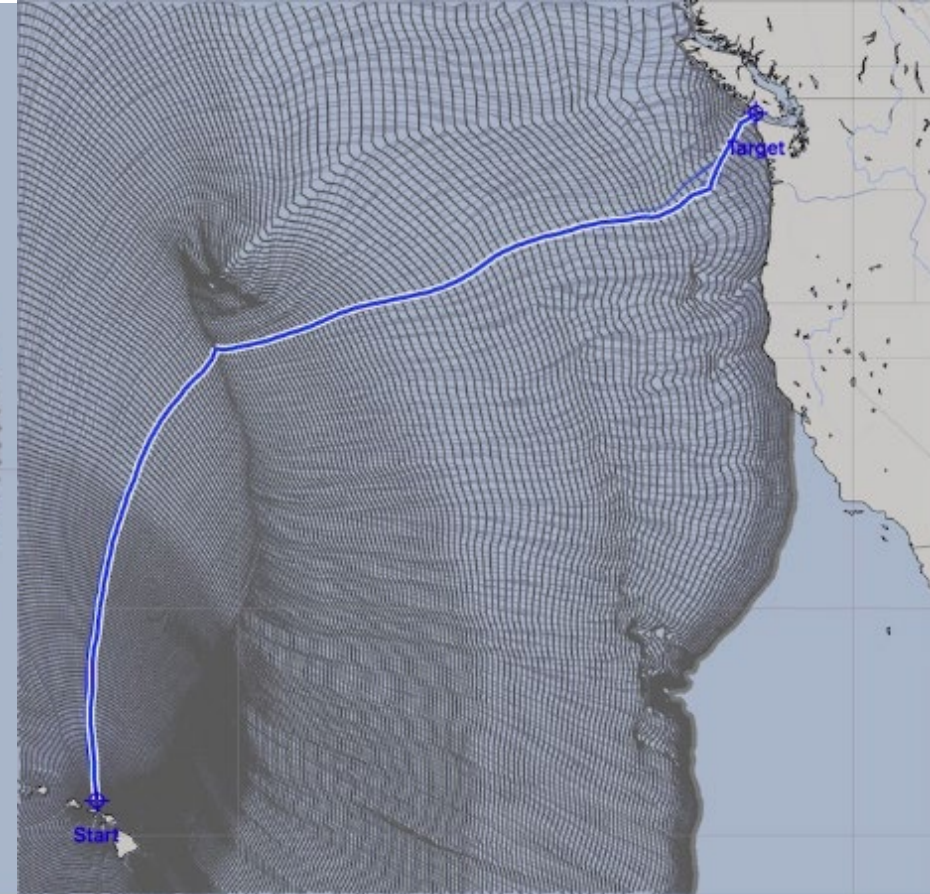
pruned

Routing principles - *isochronal*

Theory



Isochronal solution after 3 generations

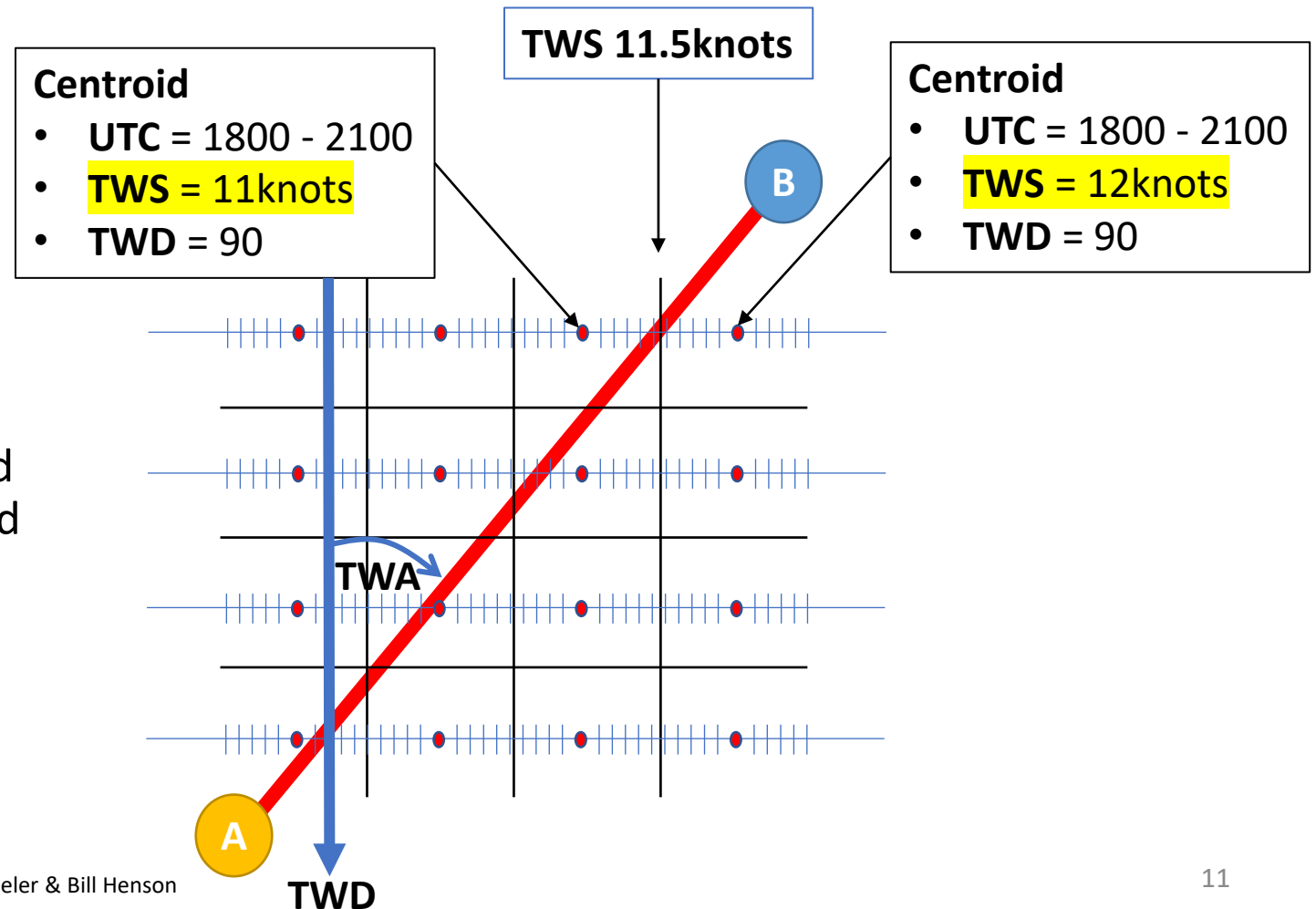


Optimal route using isochrones

Routing principles - *grid*

Theory

- **Centroid** - each grid has a 'centroid' with a data set for each time increment (from GRIB)
- **Between centroids** – data is divided incrementally (linear)
- **Route** is plotted across the grid where highest polar is achieved



Routing principles

- *the elephant in the room (sensitivity)*

Theory



FSC Topic Night: Weather routing – speed or comfort (Mark Wheeler & Bill Henson)

Routing principles

- *the elephant in the room (sensitivity)*

Theory

Settings

- Weather
- Weather data
- Tides
- Opt routing**
- Opt advanced

Configuration options

- Optimise from current position and time
- Optimise first leg only
- Optimise along great circle (grid algorithm only)
- Prefer tacks and gybes at routing steps
- Correct polar for waves if available
- Calculate reverse isochrones and sensitivity
- Use port and starboard asymmetric polars
- Motor if speed below minimum sailing speed

Land options

- Avoid land
- Avoid land high resolution
- Avoid ENC land and safety depth

Misc options

- Load previous optimal routes at startup

Data options

- Use tidal streams
- Use instrument wind
- Use weather boats
- Extend wind in time
- Extend current in time

Display options

- Optimal routes
- Isochrones
- Reverse isochrones
- Paths

Start time (lt)
10/Apr/2023 15:28:29 | Now

Resolution
Medium

180 Initial scan angle

10 Min isochrone resolution (min)

10 Custom isochrone res... (min)

1 Custom grid resolution (nm)

3000 Optimised routes to keep

Default Route colour

None Shade

1 Isochrone interval (hr)

5 Time sensitivity (min)

Map Labels: Swanbourne exclus, WSB TB 22 buoy, FSC B's 4.8m, Seaward Reef, Prohibited area, TCYC Outer finish, Coventry reef, Nat. Radio Position report heading SOUTH, Bunker Bay Turning Mark p.

5minute sensitivity

OK Cancel

Instrumentation

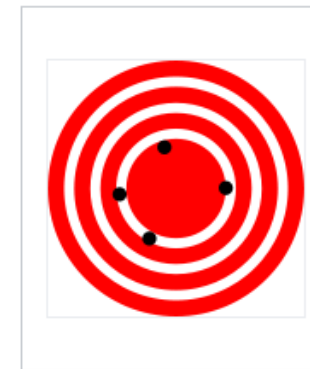
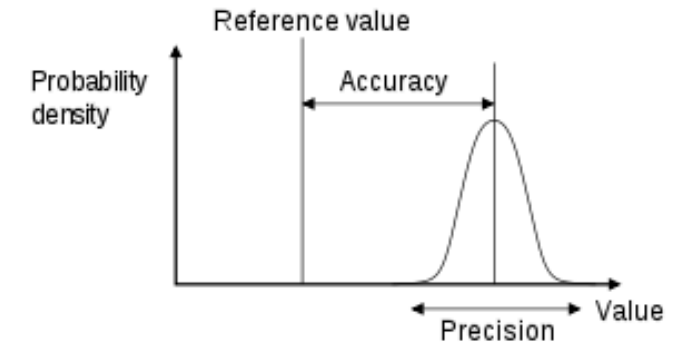
- *how accurate/precise is your data?*

Theory

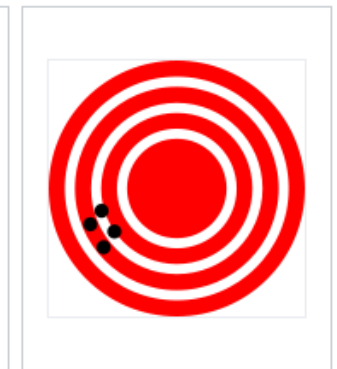
The best data is both **accurate** and **precise**.

So, how does your data stack up?

- **BSP** – same at all angles of heel (heel correction table)
- **HDG** – accurate on all points of sailing (swing your compass(es))
- **TWA** - same 'tack to tack' & 'gybe to gybe' (MHU twist, upwash correction table)
- **TWD** - same tack to tack & gybe to gybe (MHU twist, upwash correction table)
- **TWS** – same on all points of sailing (TWS upwash correction table)
- **(HDG – COG) & (BSP – SOG)** – should indicate leeway + set & drift (Leeway coefficient, HDOP, timing of ping)
- **Damping/averaging** – PhD thesis time!



Low accuracy due to low precision

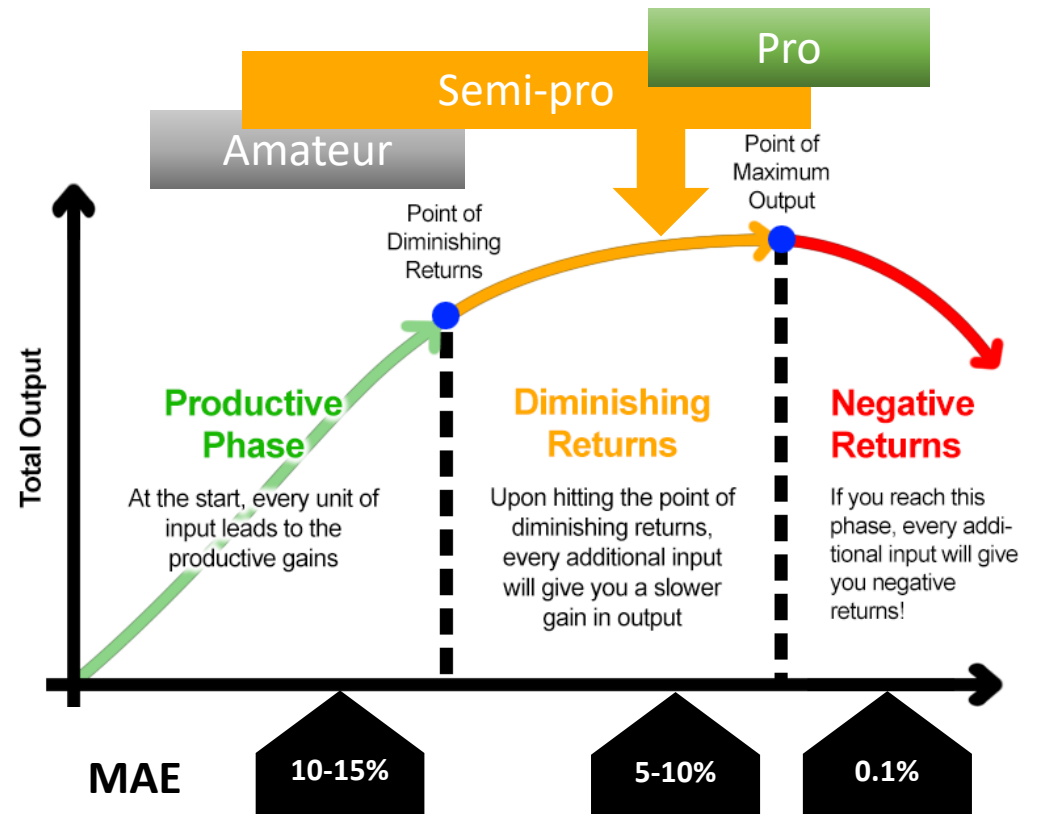


Low accuracy even with high precision

Instrumentation - *the law of diminishing returns*

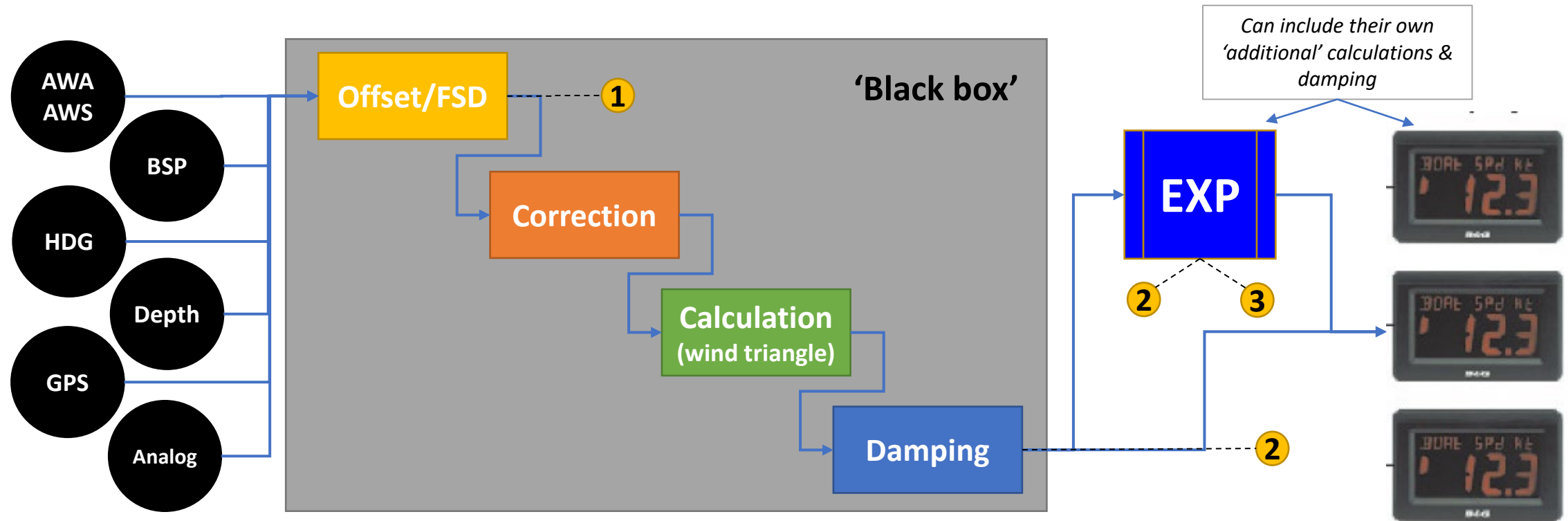
Theory

- If you want to have good routing (strategy) you need accurate instrumentation
- Increasing level of effort as higher order data is required:
 - 1st order - BSP, HDG, AWS, AWA, GPS [lat/lon, COG, SOG], etc
 - 2nd order - TWS, TWD, TWA, SET & DRIFT, etc
 - 3rd order – time to marks, targets, polars, sail Xover, etc
- Law of diminishing returns
- Not going down that rabbit hole!



Instrumentation

Theory



- **1st order** - BSP, HDG, AWS, AWA, GPS [lat/lon, COG, SOG], etc
- **2nd order** - TWS, TWD, TWA, SET & DRIFT, etc
- **3rd order** – time to mark, laylines, starting, targets, polars, sail Xover, etc

Accuracy depends on where you are getting your information from

Compounding errors

Theory

- **Route** – say ½ deg & 20m
- **Polar** – say 10%
- **GRIB** – a day out, say 10%
- **Instrumentation** – varies

- **Do the math! (another rabbit hole?)**

Addition or Subtraction

If $x = a + b - c$ then

$$\sigma_x = \sqrt{\sigma_a^2 + \sigma_b^2 + \sigma_c^2}$$

Multiplication or Division

If $x = \frac{a \times b}{c}$ then

$$\frac{\sigma_x}{x} = \sqrt{\left(\frac{\sigma_a}{a}\right)^2 + \left(\frac{\sigma_b}{b}\right)^2 + \left(\frac{\sigma_c}{c}\right)^2}$$

Exponential

If $x = a^y$ then

$$\frac{\sigma_x}{x} = y \left(\frac{\sigma_a}{a}\right)$$

Logarithmic

If $x = \log(a)$ then

$$\sigma_x = 0.434 \left(\frac{\sigma_a}{a}\right)$$

Anti-logarithmic

If $x = \text{antilog}(a)$ then

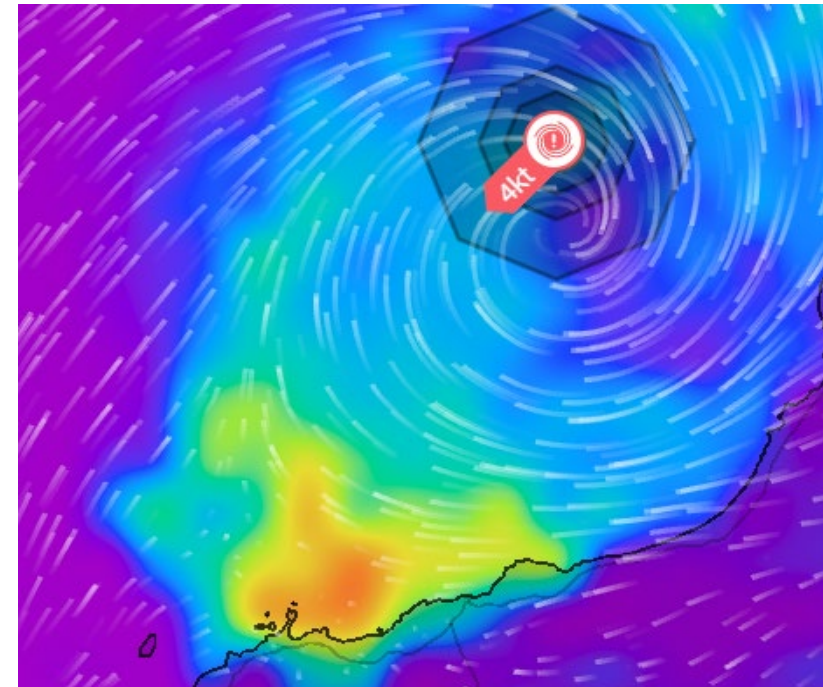
$$\frac{\sigma_x}{x} = 2.303(\sigma_a)$$

- **Theory** - VMG, VMC & XTE
- **Routing essentials** - course, polar & GRIB
- **Elephant in the room** – sensitivity
- **Instrumentation:**
 - law of diminishing returns – set your expectations
 - accuracy & precision - to get the best out of routing
- **Compounding errors** – holy @\$%, what am I worrying about?



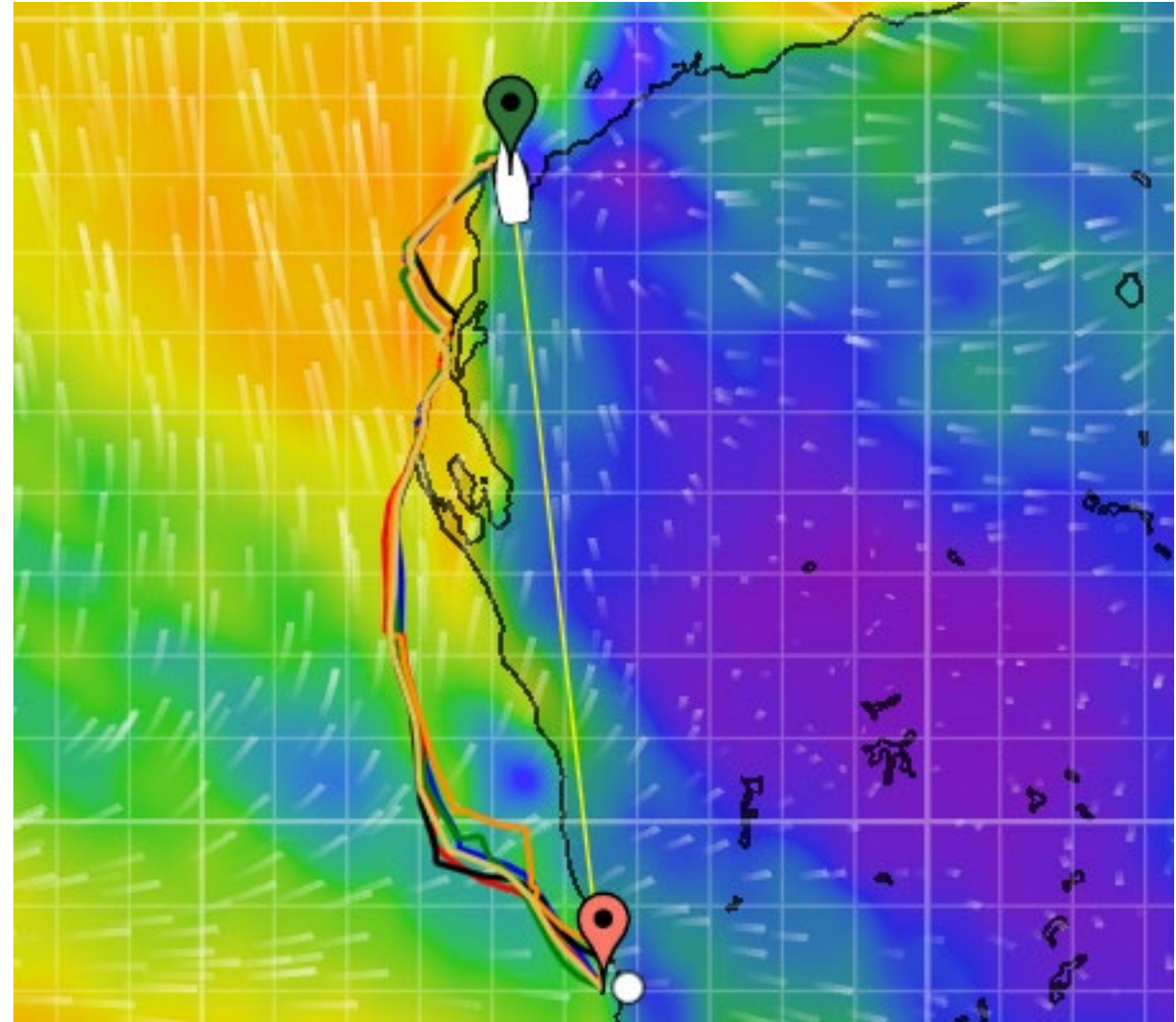
- Weather routing run on PW server, not on board
- Subscription fee
 - Standard level US\$250/year
 - Professional level US\$500/year
 - 3 month service available
- Multiple weather models (9)
- Weather routing & departure planning
- Tutorials, videos, help desk

- Gust and instability (CAPE) forecast



Weather routing

- Select boat polar from list
- Apply adjustments for your style of sailing
 - Upwind
 - Downwind
 - Night
 - Speed or comfort
- Set start, end point and start time



Departure planning

- Select polar, adjustments, route
- Select start date, frequency
- Run departure planning
- Analyse results

- Example Exmouth to Shark Bay

	Day 1	Day 4
Passage time days	2.3	1.8
Max. wind speed	30	20
Upwind	89%	35%
Upwind > 15 knots	86%	9%

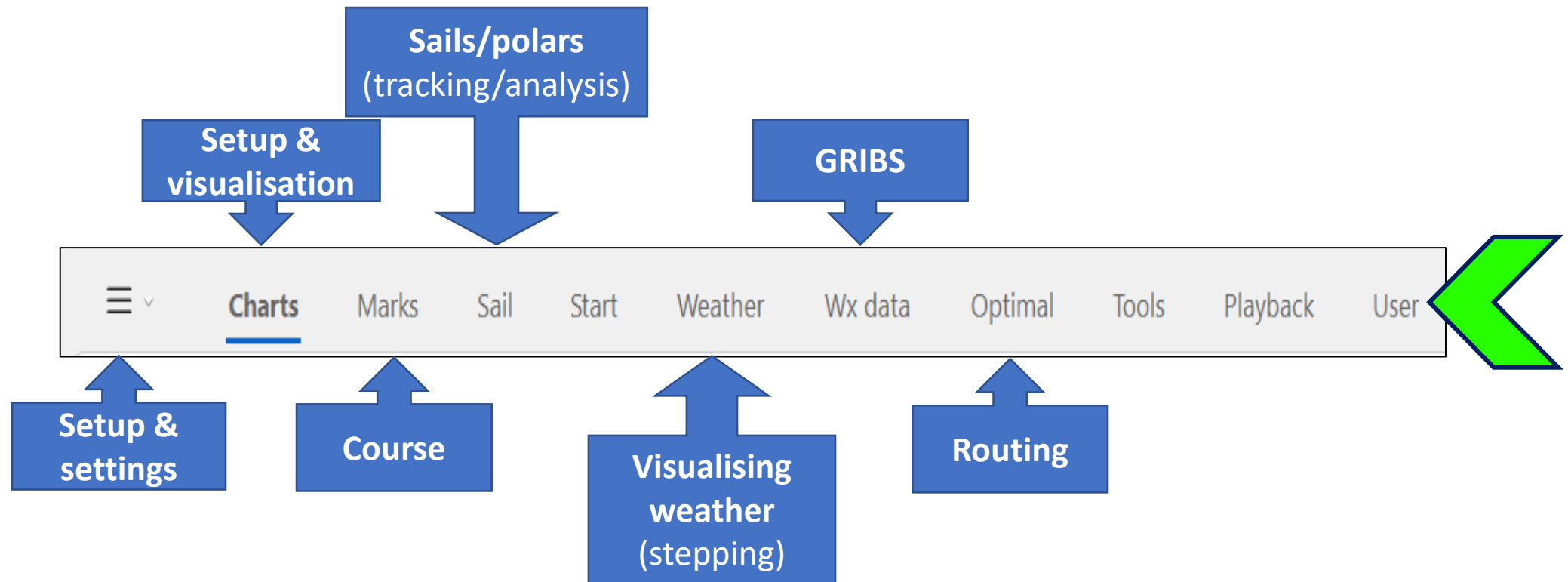
Conclusions

- Lower cost introduction to weather routing
- Easy to use, good on-line support & helpful support
- Internet connection is necessary
 - Inshore: mobile phone (little or no service north of Kalbarri)
 - Offshore: satellite
 - Offshore app is recommended
- Practice at least 2-4 weeks before departure
- Adjust route based on actual conditions
- Weather routes are a guide, not gospel !

Expedition

– a quick tour of ‘the ribbon’

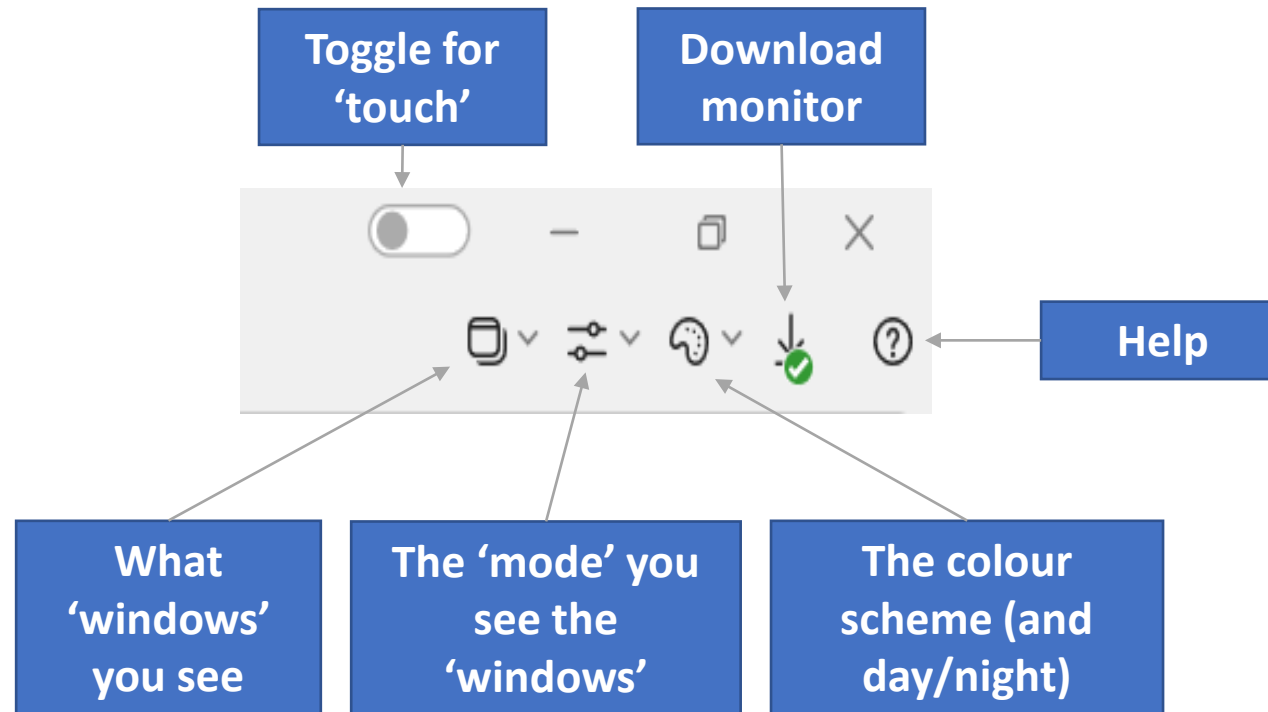
Practical



Expedition

– a quick tour of ‘the ribbon’ (the other bit)

Practical



Expedition

– a quick tour of Setup & Settings

Practical

The image shows two side-by-side screenshots of the Expedition software interface. The left screenshot is titled 'Setup' and shows a vertical menu with items: Settings, Exp data folder, Windows keyboard, Full screen, Save screen, Calibrations, Instruments, Applications, Scheduler, Check for updates, and Licences. A large green arrow points to the 'Settings' item. The right screenshot is titled 'Settings' and shows a vertical list of categories: System, Files, Internet, Display, Charts, C-MAP, Alarms, Alternating, User, Logging, Channels, User channels, Track, Racing / start, Weather, and Weather data. Green callout boxes with arrows point to each of these categories, providing a brief description of what each section covers. A sub-menu for 'Tides' is also shown, with 'Opt routing' and 'Opt advanced' options highlighted by callouts.

Setup

- Settings
- Exp data folder
- Windows keyboard
- Full screen
- Save screen
- Calibrations
- Instruments
- Applications
- Scheduler
- Check for updates
- Licences

Settings

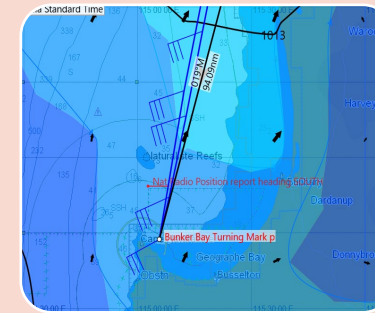
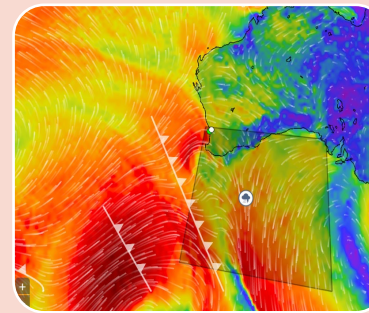
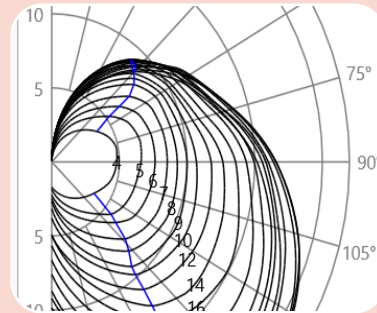
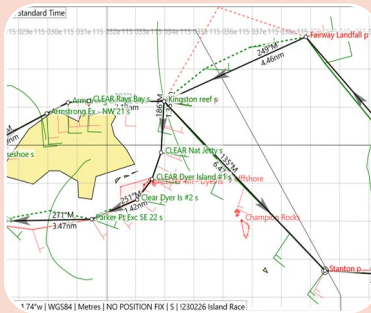
- System – basic setup
- Files
- Internet
- Display – what you see on the screen
- Charts
- C-MAP
- Alarms
- Alternating
- User
- Logging
- Channels
- User channels
- Track – how your boat track is displayed
- Racing / start
- Weather – how you see 'weather'
- Weather data – GRIB location

Tides

- Opt routing – routing setup
- Opt advanced – more setup

Expedition - routing checklist ('modifiers')

Practical



Course/marks

- Magnetic/true
- Active course
- Rounding
- Avoid land
- Safety depth
- Race notes
- Iso/grid
- 'Risk'

Polar

- Appropriate selection
- Nav/Perf/Start
- Night & day %

GRIB

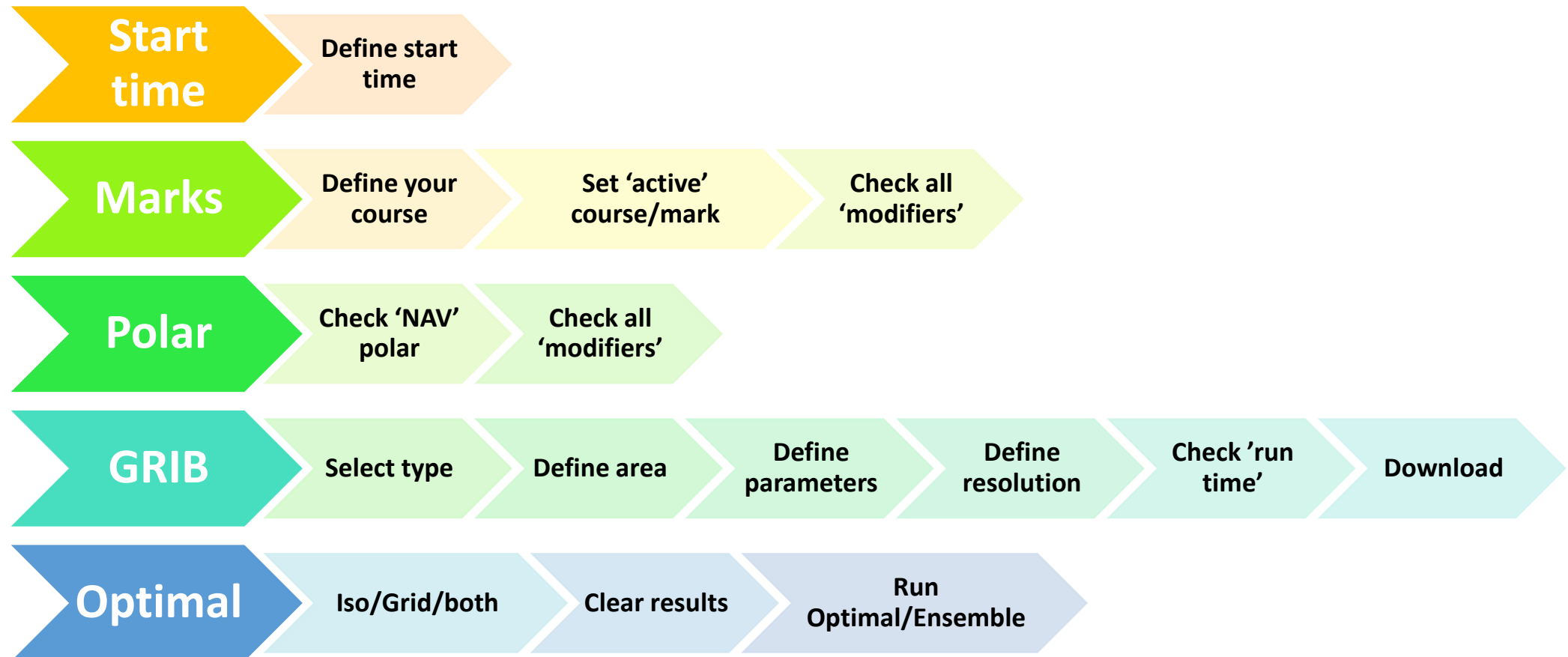
- Days out
- Twist TWD
- Adjust TWS
- Wave/current

Optimal route

- Start time/from now
- Iso/grid/both
- Tack/gybe penalty
- Resolution
- Errors

Expedition - routing process

Practical



Expedition outputs - run sheet

Practical

W. Australia Standard Time Mark	Sail	Twtd*M	TwS	Twg	Twa
26/02/2023 9:10S	FULL MAIN;J1.5	68	7.6	10.3	-24
26/02/2023 9:11	FULL MAIN;J1.5	68	7.6	10.2	52
26/02/2023 9:12	FULL MAIN;J1.5	68	7.6	10.2 (-1)	
26/02/2023 9:15	FULL MAIN;J1.5	68	7.5	10.2 (-21)	
26/02/2023 9:21 !Day Bouy	C0;FULL MAIN	67	7.4	10.4	109
26/02/2023 9:42	C0;FULL MAIN	67	6.8	8.1	109
26/02/2023 10:05 Fairway Landfall	A1;FULL MAIN	66	5.7	6.6	-160
26/02/2023 10:47	A1;FULL MAIN	70	3.7	4.1 (-163)	
26/02/2023 11:26 Kingston reef	C0;FULL MAIN	92	3.3	3.8	-94
26/02/2023 11:36	C0;FULL MAIN	98	3.6	4.1	-87
26/02/2023 11:45 CLEAR Nat Jetty	C0;FULL MAIN	105	3.9	4.6	-97
26/02/2023 11:50	C0;FULL MAIN	110	4.1	4.8	-92
26/02/2023 11:55 CLEAR Dyer Island	C0;FULL MAIN	116	4.2	5	-105
26/02/2023 11:59	C0;FULL MAIN	121	4.4	5.2	-100
26/02/2023 12:02 Mark2	C0;FULL MAIN	127	4.5	5.4	-106
26/02/2023 12:10	A1;FULL MAIN	139	4.9	5.9	-126
26/02/2023 12:18 Parker Pt Exc SE 22	A1;FULL MAIN	151	5.2	6.3	-120
26/02/2023 12:33	C0;FULL MAIN	167	6.1	7.4	-104
26/02/2023 12:47 CV Ex- SE	C0;FULL MAIN	177	7.3	8.9	-106
26/02/2023 12:50	C0;FULL MAIN	179	7.6	9.2	-96
26/02/2023 12:53 CV Ex - SW	A1.5;FULL MAIN	181	7.9	9.6	-162
26/02/2023 12:57	A1.5;FULL MAIN	183	8.1	9.8 (-141)	
26/02/2023 13:04 CV Ex - NW	A3;FULL MAIN	187	8.5	10.4	125
26/02/2023 13:08	A3;FULL MAIN	189	8.6	10.4	120
26/02/2023 13:12 CLEAR Horseshoe	A3;FULL MAIN	190	8.6	10.5	124
26/02/2023 13:21	A3;FULL MAIN	192	8.6	10.6	126
26/02/2023 13:29 Armstrong Ex - NW 21	A3;FULL MAIN	195	9	11.1	128
26/02/2023 13:31	A3;FULL MAIN	196	9.1	11.3	129
26/02/2023 13:34 Armstrong Ex - NE 21	C0;FULL MAIN	197	9.3	11.5	109
26/02/2023 13:35	C0;FULL MAIN	197	9.5	11.8	109
26/02/2023 13:37 CLEAR Rays Bay	C0;FULL MAIN	198	9.7	12	106
26/02/2023 13:43	C0;FULL MAIN;GS	200	10.5	13.1	108
26/02/2023 13:49 Kingston reef	FULL MAIN;J1.5	203	11.3	14.2	65
26/02/2023 14:03	FULL MAIN;J1.5	205	12.5	15.9	68
26/02/2023 14:16	FULL MAIN;J1.5	209	13.3	17.1	78
26/02/2023 14:27 Stanton	A3;C0;FULL MAIN;GS	213	13.9	18.5	122
26/02/2023 14:36	C0;FULL MAIN;GS	217	14	19.4	118
26/02/2023 14:46 South Mole Finish 22adj	A3;GS;REEF 1	220	13.3	20	122

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Expedition outputs - analysis

Practical

2 routes
 First start 26-Feb-2023 09:10:00 W. Australia Standard Time
 Last start 26-Feb-2023 09:10:00 W. Australia Standard Time
 Min time 05h 16m 14s
 Mean time 05h 26m 15s
 Max time 05h 36m 15s
 Mean distance 42.58nm

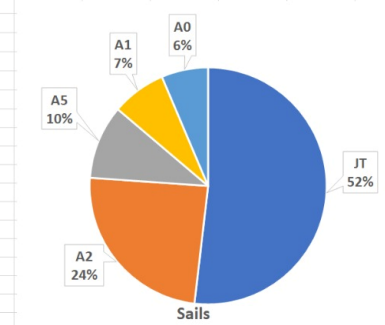
tws\TWA	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sails	Hours	%
A1.5	0.4	7.4
A2	0.05	0.9
A3	0.76	14
J1.5	0.61	11.2
J2.5	0.05	1
GS	0.21	4
SS	0.1	1.8
C0	1.29	23.8
A1	1.95	35.9
Total hours	5.44	
FULL		
MAIN	5.36	98.6
REEF 1	0.08	1.4

Conditions																			
TWS/TWA	30	40	50	60	70	80	90	100	110	120	130	140	150	160	Total				
40																			
38																			
36																			
34																			
32																			
30																			
28																			
26																			
24																			
22																			
20																			
18	1.2%						1.1%	1.7%	1.7%	1.7%	1.7%	1.4%						7.6%	
16	0.2%						4.5%	6.8%	3.4%	3.4%	3.4%	1.4%			0.3%			21.0%	
14	0.2%								12.7%	4.8%					3.0%			20.6%	
12						3.4%		3.4%	5.5%						0.7%			13.2%	
10								4.1%							3.9%			8.1%	
8						1.7%	1.7%	0.8%	4.2%						1.3%	1.3%		11.1%	
6										0.0%	5.1%	1.7%			3.4%			10.2%	
4																			
2																			
Total	1.7%					1.7%	5.1%	5.5%	12.7%	31.6%	9.9%	6.5%	3.1%		4.7%	9.2%			
	UW (30-50)				Reach (60-90)				Broad reach (100-130)				DW (140 - 160)						

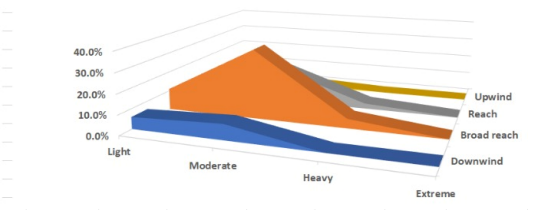
Sail metrics

Sails	Hours	%
JT	10.48	47.5
A2	4.9	22.2
A5	2.04	9.2
A1	1.5	6.8
A0	1.29	5.8
Code 2	0.85	3.8
Code 1	0.75	3.4
Code 3	0.27	1.2
Total hours	22.09	



Summary conditions

Point	Light	Moderate	Heavy	Extreme	Total
Downwind	6.0%	7.9%			13.9%
Broad reach	11.0%	35.3%	4.8%		51.1%
Reach	4.2%	18.1%	2.8%		25.0%
Upwind		1.7%			1.7%
Total	21.2%	62.9%	7.6%		

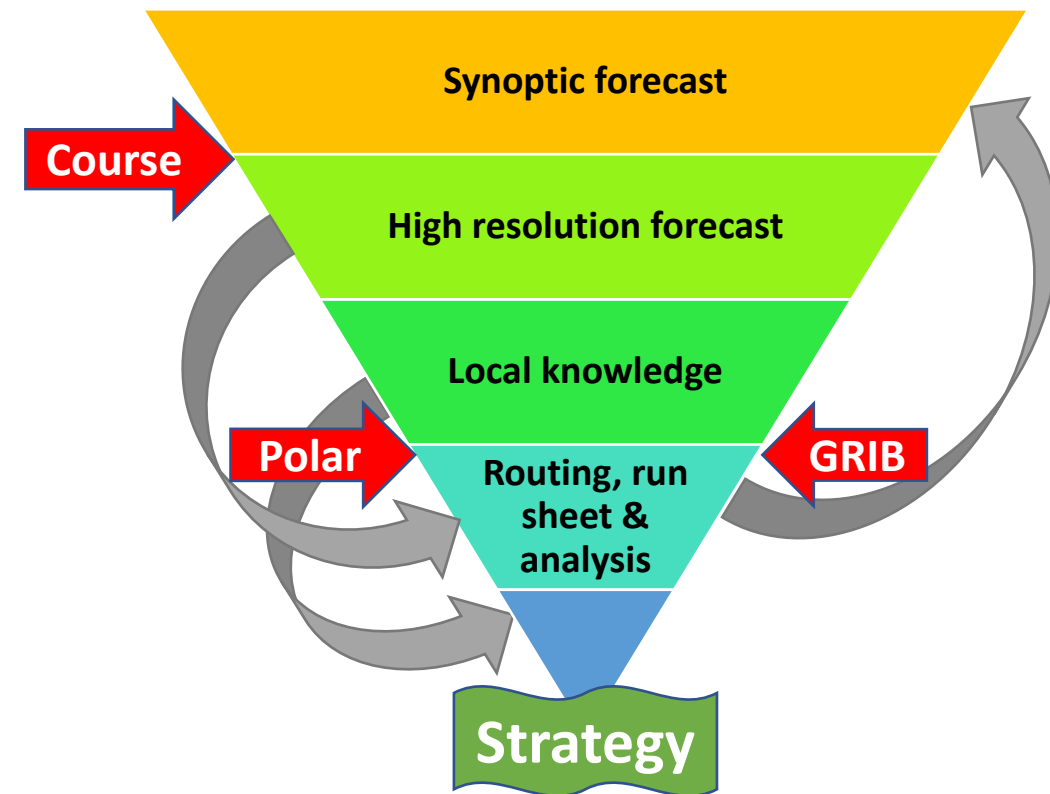


Expedition - review & analysis

Practical

What is the data telling you:

- **Route** – what is it telling you? (Step against the weather and ‘read’ the wind barbs)
- **Run sheet** – what is it telling you?
- **Analysis** – what is it telling you?
- **What is your strategy?** (your game plan)
- **Management of change?** (how will you manage inevitable change?)
- Ultimate output is actually a **strategy**, not a route!



- **Be calm & systematic** – your system WILL freeze, shutdown and restart (how long does that take?)
- **Current & wind** - >12knots 5% current with wind
- **Meteograms** – look for highest rate of change (but remember ‘linear interpolation’ between)
- **Remote desktop**
- **MetEye** (access model)
- **Blue line**
- **Track colour and percentage**
- **Number box and average** - over a period of time
- **Predictor lines** – length = time
- **Excel/stripchart is your friend**
- **Electronics & saltwater** – treat them like your life depends on them

Expedition

- **Will Oxley** - [Expedition Navigation Software: A "Gentle" Introduction, Modern Race Navigation: Expedition Software in Action, Using Expedition Software for Race Starts](#)
- **Greg Brougham** - [Cruising with Expedition](#)

Weather

- **Meteye**
- **BOM** – especially high res satellite photgrametry
- **PredictWind**
- **Sailflow**
- **Windy**
- **Seabreeze**
- **Expedition (itself)**

Social media

People

- [Artie Means](#)
- [Campbell Field](#)
- [Chelsea Carlson](#)
- [Chris Bedford](#)
- [Johan Barne](#)
- [Miguel Sanchez-Cuenca \(Capi\)](#)
- [Nicolas Lunven](#)
- [Peter Isler](#)
- [Simon Rowell](#)
- [Stan Honey](#)
- [Will Oxley](#)

Locals

- **Lynnath Beckley**
- **Jonathan Clough**
- **Paul Eldrid**
- **Kingsley Piesse**
- **Adam Shand**

- **Routing** is actually **strategy, scenario planning, ‘what if’ analysis, game planning**
- Whereas **Navigation** is (a) knowing where you are and (b) where you can go to safety
- **Theory** - informs your decision making – big picture first, then down to detail
- **Instrumentation** – calibration is a journey (and a long one!), but its worth it!
- **Routing:**
 - Course
 - Polar
 - GRIB
 - Understand the modifiers
- **Review & analysis** – vitally important to:
 - turn data into information
 - separate fact from opinion
- **Reach out and ask for help**

Q&A



FSC Topic Night: Weather routing – speed or comfort (Mark Wheeler & Bill Henson)

A blue racing yacht with white and black sails is sailing on a dark, choppy sea. The yacht has the number '101' on its hull and 'F 0052' on its black sail. The background features a dramatic, dark cliffside with a lighthouse on top. The sky is overcast.

Thankyou

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