MacCready from pre-K to PhD

Pasco 2017
John Cochrane

How to fly faster & further

1) Climb better 2) Climb better 3) Climb better

Avoid bad lift.

1. Weak lift hurts more than strong lift helps.
2. Average of 2 kts and 10 kts is 3.33 kts not 6 kts:

   1000’ @ 2 kts = 5 min. 1000’ @ 10 kts = 1 min. 2000’/6 min = 3.33 knots.
3. 2 x 4 knots is better! “Little harm ever came from climbing in smooth 5 kts lift.”

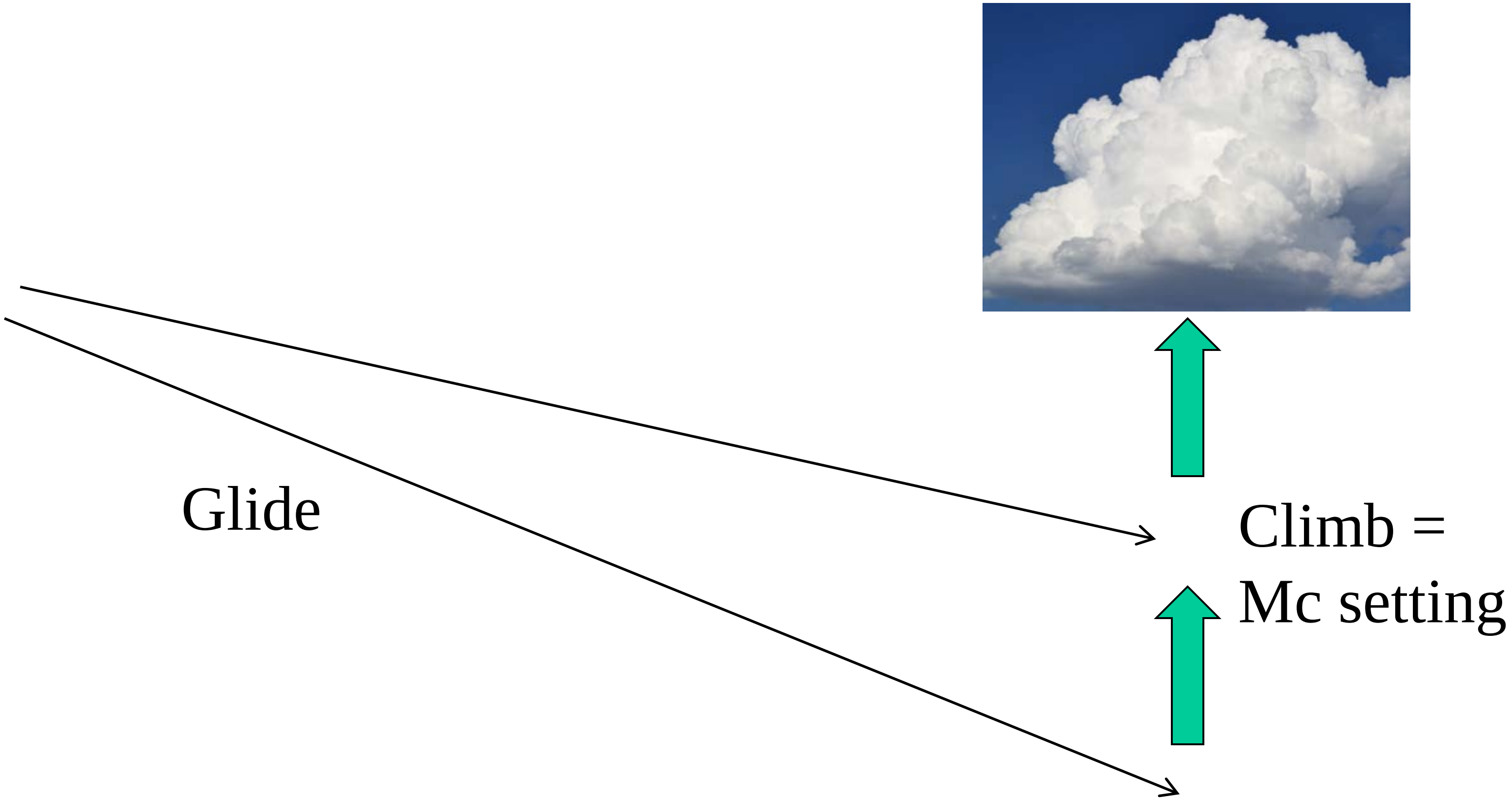
Leave bad lift.

1. Set a value (Mc) – 2-3 knots. If averager < Mc you leave. *Now. Yes*, ***Now!***
2. If lift is not increasing at 60deg off course, do not continue turn.
3. Common errors. Searching, going back.
4. Most brilliant recentering is actually leaving in disgust, blundering in to the core.
5. Psychology:
   a. Confidence—there will be lift ahead and you will find it. (Weather, experience)
   b. Why am I scared? How often have I actually landed from this situation?

More

Cruise faster; make better strategic decisions, (generalized) “MacCready theory.” *All decisions come down to altitude vs. time.*

MacCready 101 -- Scenario

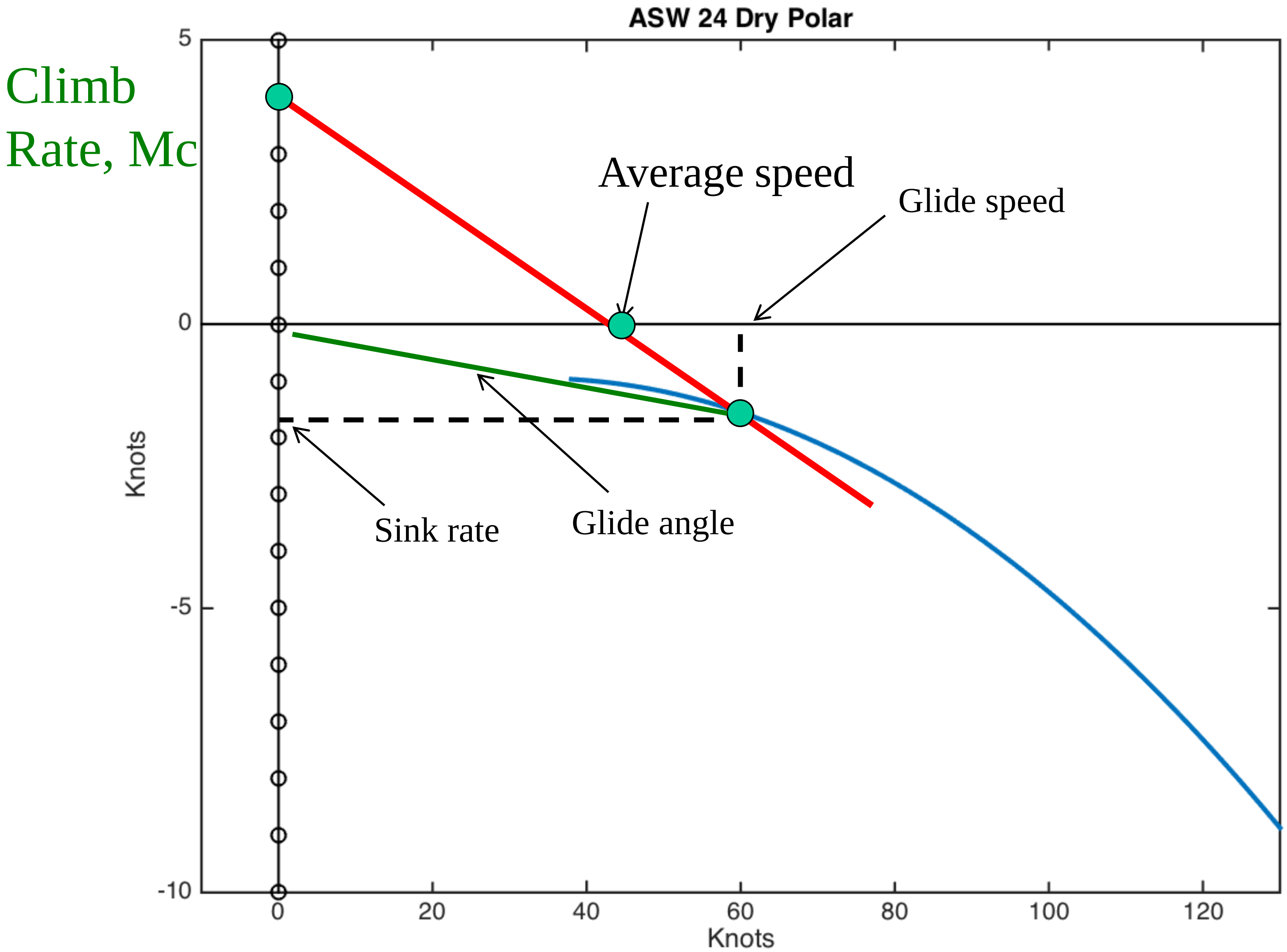


Was: What is lift in the next thermal?

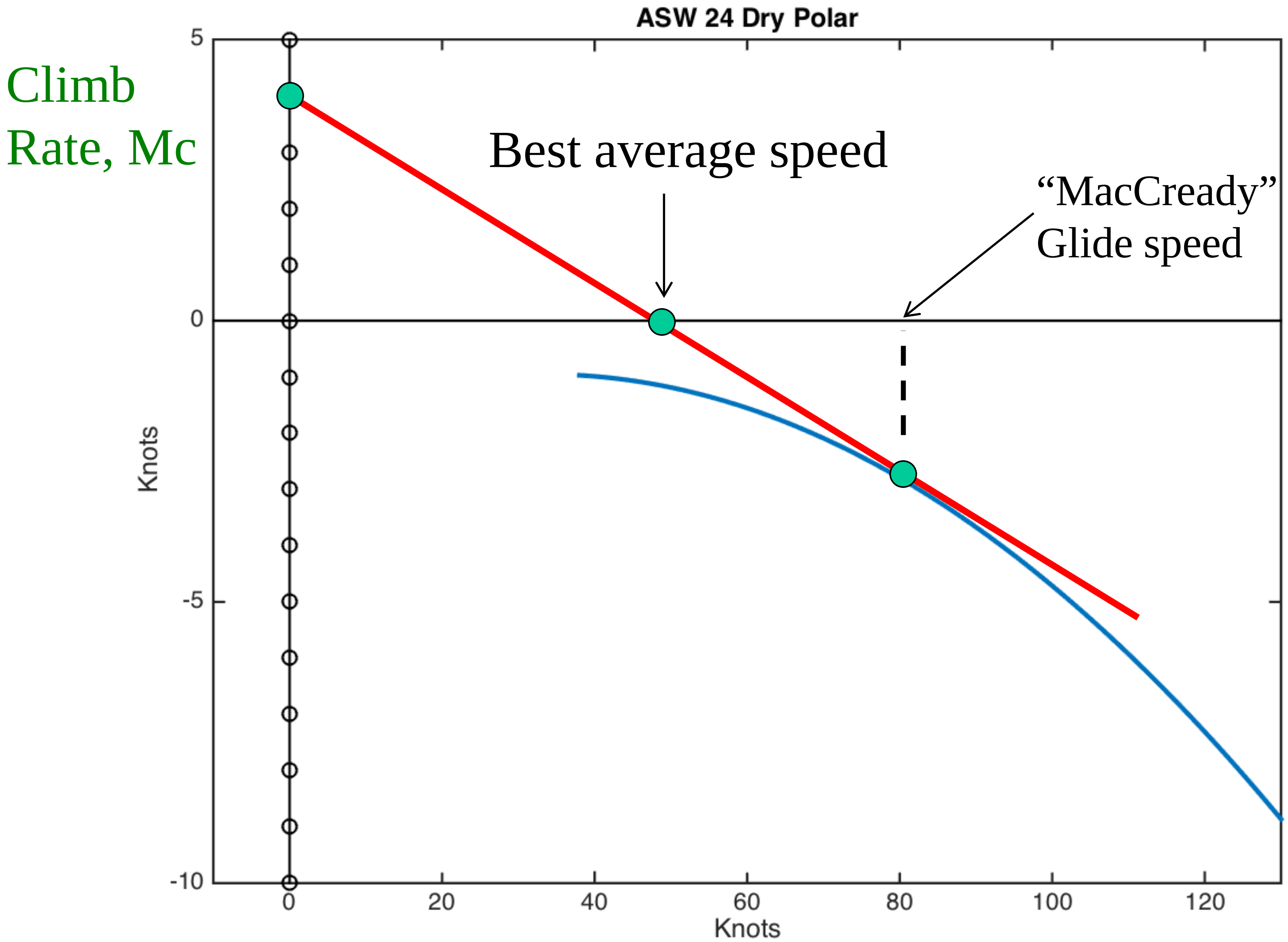
Now: What is the minimum (totally smooth, no search time) lift you would stop and take right now?

Both: How fast to fly?

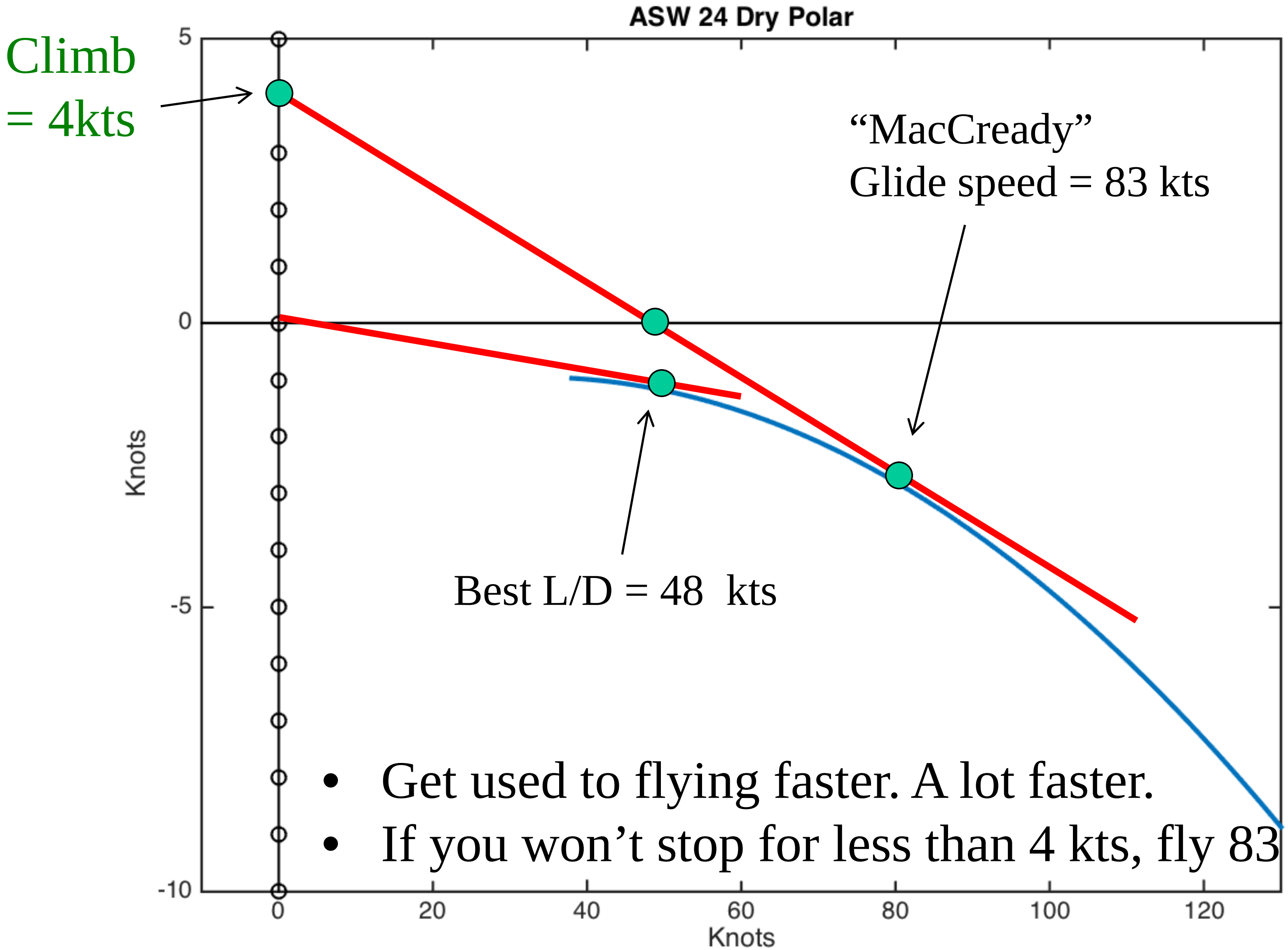
MacCready 101



MacCready 101



MacCready 101



- Get used to flying faster. A lot faster.
- If you won’t stop for less than 4 kts, fly 83

Numbers: Target Cruise Speeds

Dry ASW 24

Basic MacCready speeds and average speeds

Mc (kts)	Glide (kts)	L/D	D/L ft/mi	- Avg Speed- (mph)	(kph)	
0	47	42	125	0	0	-Almost never used
1	58	39	134	27	44	-Desperate
2	68	35	152	39	63	-Cautious
3	76	30	173	48	77	-Doing fine everyday setting
4	83	27	195	54	87	-Ripping, confident
5	90	24	216	60	96	-Not used except heavy sink, final glide,
6	97	22	237	65	104	wave, ridge, Tonopah, or other
7	102	20	258	69	111	special cirucumstance.
8	108	19	278	73	117	(especially standard class)

- Cruise faster!
- But not that fast! Why do we use Mc 3-4 glides in 6 knot lift? Coming.
- Average speeds 70+ come from gliding in lift, not booming thermals and mad glides
- *Your* thermal, not 7Vs thermal! If you‘re not as good at climbing, fly slower.

Dry ASG 29
Basic MacCready speeds and average speeds

Mc (kts)	Glide (kts)	km/h	L/D	D/L ft/mi	Avg Spd (kts)	Avg Spd (mph)	Avg Spd (kph)
0	53	97	51	103	0	0	0
1	62	114	48	109	27	31	50
2	69	129	43	124	38	44	71
3	76	142	37	141	46	52	84
4	83	154	33	160	51	59	94
5	89	165	30	179	55	64	103
6	95	175	27	198	59	68	110
7	100	185	24	217	63	72	116
8	105	194	22	236	66	76	122
9	110	203	21	255	69	79	128

Mc Settng is roughly same for different gliders/water. Speed is not!

Know speed for block speed flying!

Wet ASG 29
Basic MacCready speeds and average speeds

Mc (kts)	Glide (kts)	km/h	L/D	D/L ft/mi	Avg Spd (kts)	Avg Spd (mph)	Avg Spd (kph)
0	69	127	50	106	0	0	0
1	79	146	48	110	30	34	55
2	87	162	44	120	44	50	81
3	95	177	40	132	53	61	98
4	103	190	36	146	60	69	111
5	110	203	33	161	66	76	122
6	116	215	30	175	71	81	131
7	122	226	28	190	75	86	139
8	128	237	26	205	79	91	146
9	134	248	24	219	83	95	153

Seeyou: virtually all pilots at western 18m nats fly 95-105

Avg: important to glide in lift!

Don’t forget to speed up in sink! Don’t slow too much in lift!

Dry ASW 27

Basic MacCready speeds and average speeds

Mc (kts)	Glide (kts)	km/h	L/D	D/L ft/mi	|--- Avg Spd (kts)	(mph)	---| (kph)
0	55	103	48	110	0	0	0
1	65	120	46	116	27	31	49
2	73	135	41	129	38	44	71
3	80	148	36	146	46	53	85
4	87	160	32	163	52	60	96
5	93	172	29	182	57	65	105
6	99	183	26	200	61	70	113
7	104	193	24	218	64	74	119
8	109	202	22	236	68	78	126
9	114	211	21	254	71	82	131

Wet ASW 27

Basic MacCready speeds and average speeds

Mc (kts)	Glide (kts)	km/h	L/D	D/L ft/mi	|--- Avg Spd (kts)	(mph)	---| (kph)
0	67	125	47	112	0	0	0
1	79	146	45	117	29	33	53
2	89	164	41	128	43	49	79
3	97	180	37	141	52	60	96
4	105	195	34	156	59	68	110
5	113	209	31	171	65	75	121
6	120	222	28	186	70	81	130
7	127	235	26	201	75	86	139
8	133	246	24	216	79	91	147
9	139	258	23	230	83	96	154

Faster than 29!

Dry Std Cirrus

Basic MacCready speeds and average speeds

Mc (kts)	Glide (kts)	km/h	L/D	D/L ft/mi	Avg Spd (kts)	Avg Spd (mph)	Avg Spd (kph)
0	51	95	37	145	0	0	0
1	58	108	35	150	22	25	41
2	64	119	32	163	32	37	60
3	70	129	30	179	39	45	72
4	75	138	27	197	44	51	82
5	79	147	24	216	48	55	89
6	84	155	22	235	52	59	96
7	88	163	21	255	55	63	102
8	92	171	19	275	58	66	107
9	96	178	18	294	60	69	112

Older gliders fly a lot slower!

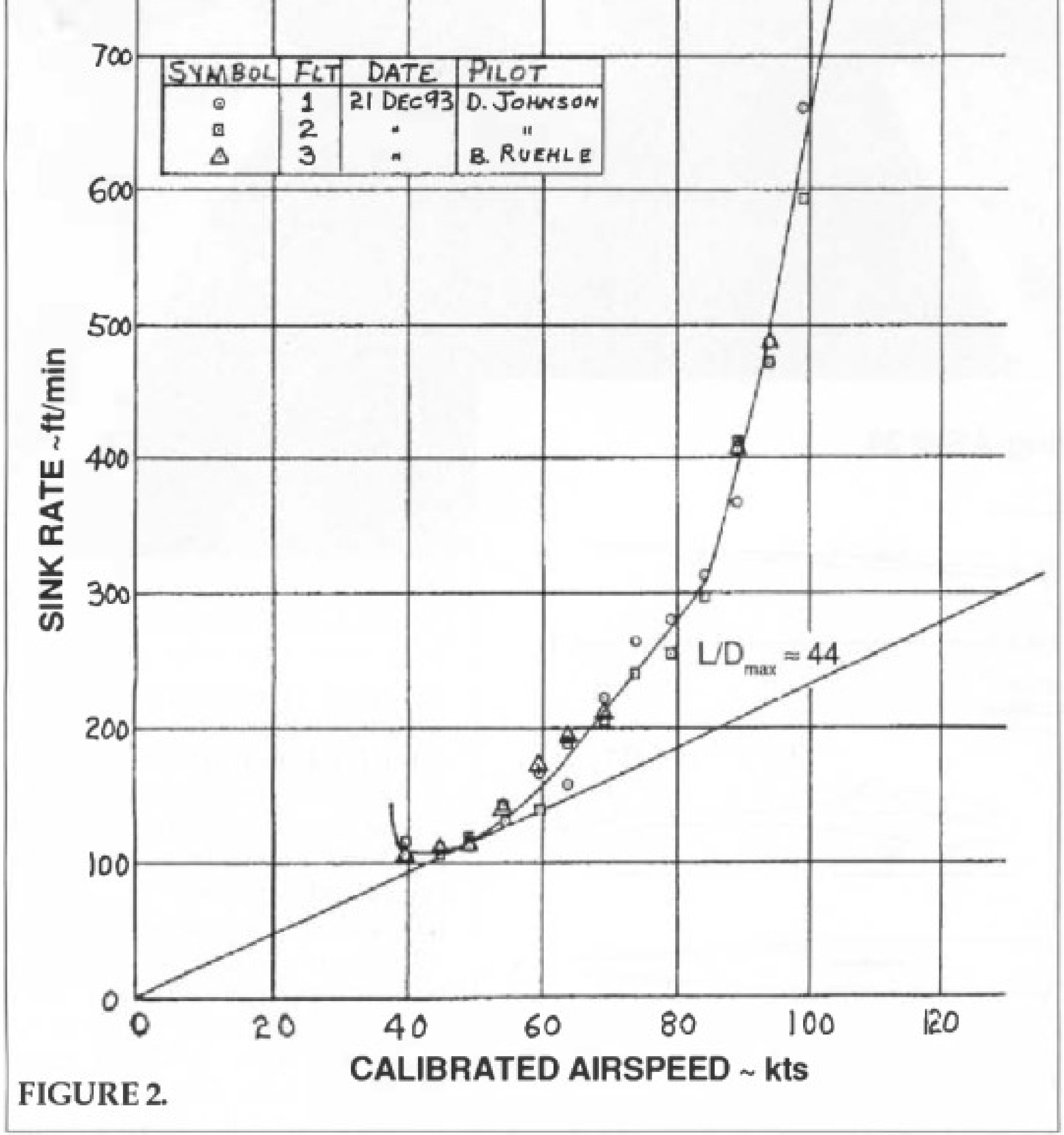
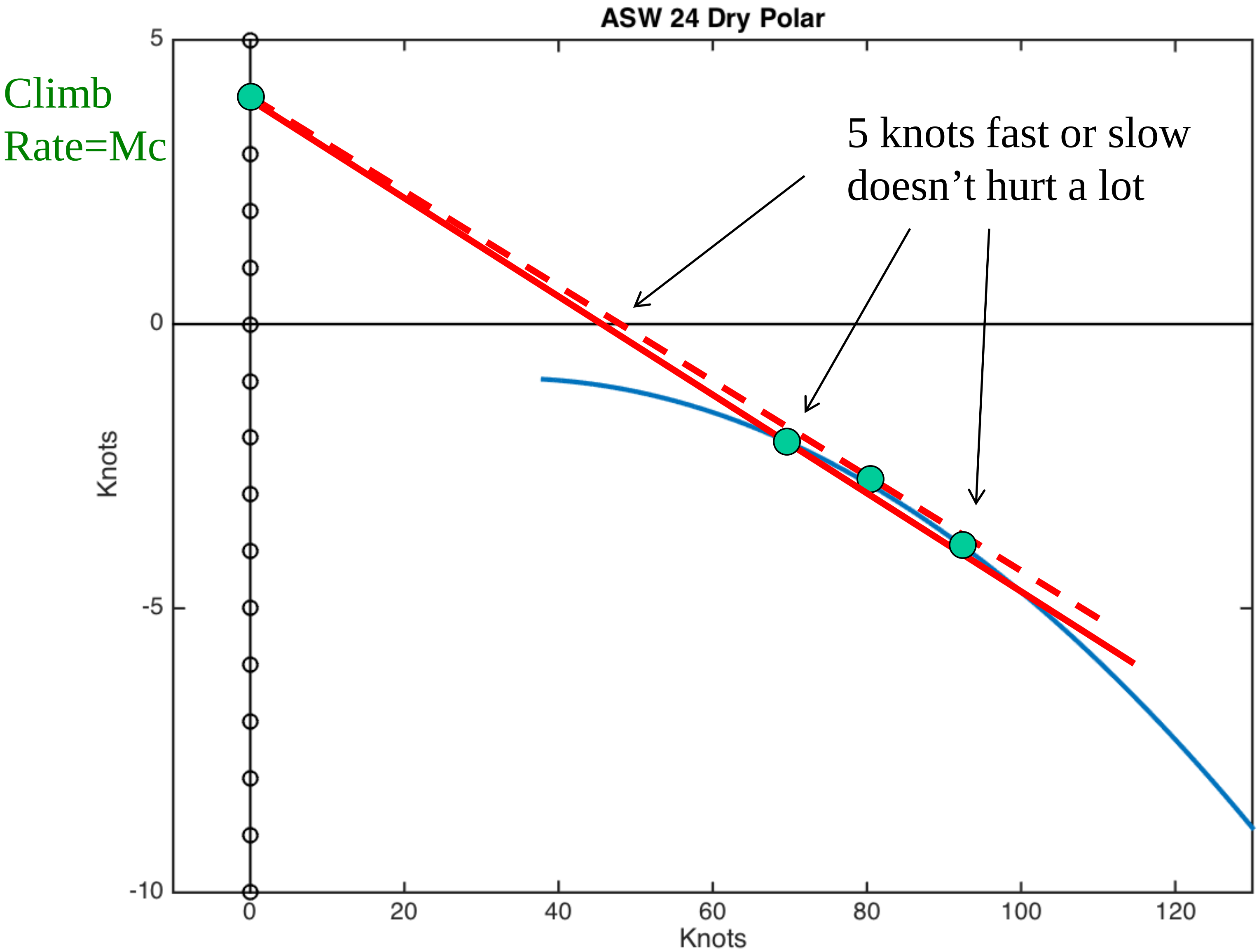


FIGURE 2.

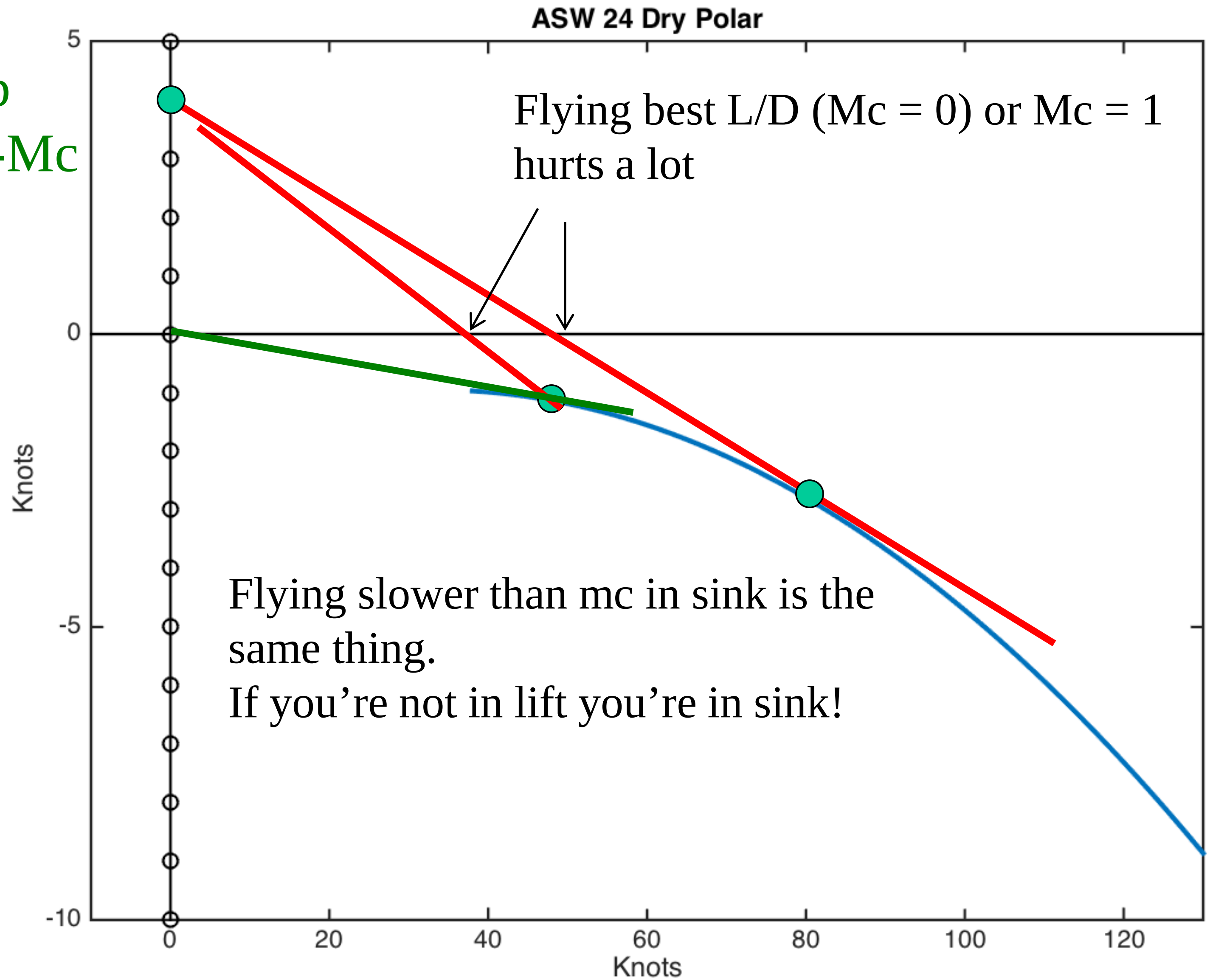
Non quadratic polars. Mc > 2
Fly standard class at 60 or 80.
Bottom surface separation

MacCready 101



MacCready 101

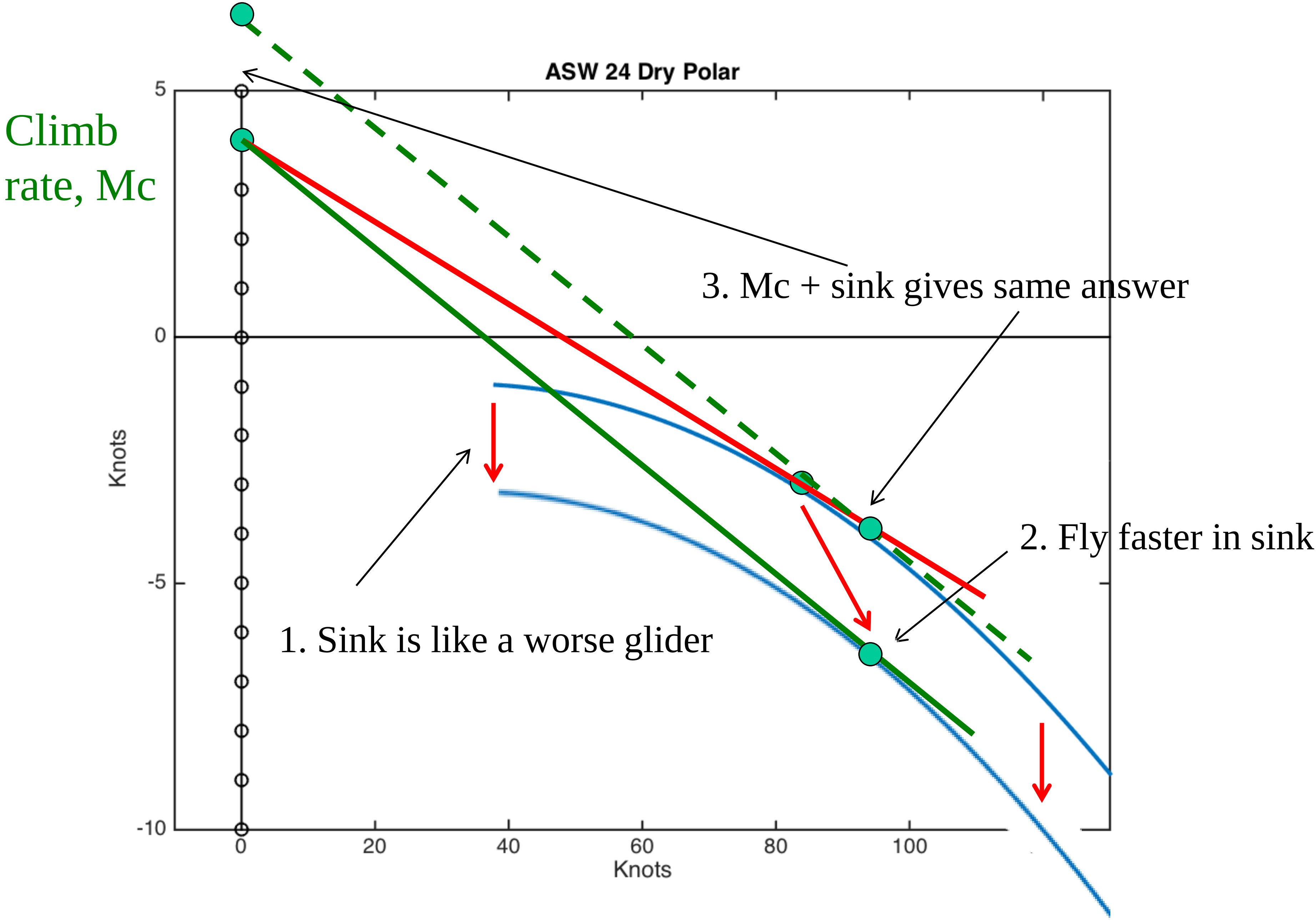
Climb Rate -Mc



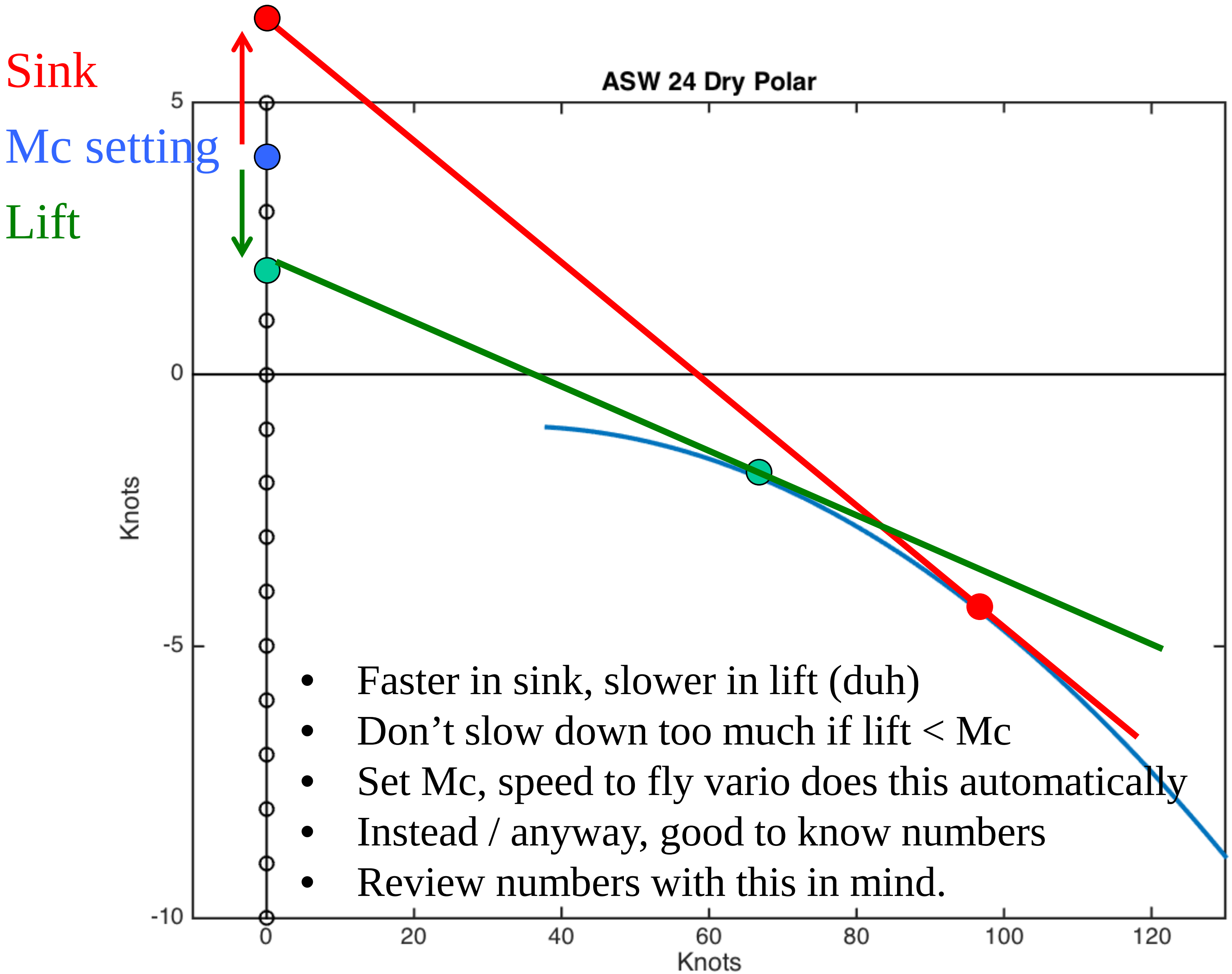
Flying best L/D (Mc = 0) or Mc = 1 hurts a lot

Flying slower than mc in sink is the same thing.
If you’re not in lift you’re in sink!

MacCready 101– Lift and Sink



MacCready 201– Lift and Sink



- Faster in sink, slower in lift (duh)
- Don’t slow down too much if lift < Mc
- Set Mc, speed to fly vario does this automatically
- Instead / anyway, good to know numbers
- Review numbers with this in mind.

Numbers: Lift/sink

Dry ASW 24
Basic MacCready speeds and average speeds

Mc (kts)	Glide (kts)	L/D	D/L ft/mi	- Avg Speed- (mph)	(kph)	
0	47	42	125	0	0	-Cautious + 2 kts lift
1	58	39	134	27	44	
2	68	35	152	39	63	-Cautious
3	76	30	173	48	77	
4	83	27	195	54	87	-Cautious + 2 kts netto sink = 4 kts vario sink
5	90	24	216	60	96	
6	97	22	237	65	104	- Cautious = 4 kts (wave) sink
7	102	20	258	69	111	
8	108	19	278	73	117	

Don’t fly too slow in persistent sink!

Practical dolphin / speed flying

- Block speeds – don’t chase vario.
- What’s ahead matters – slow for smooth lift, big clouds; speed up in consistent/ predictable sink.
- *Change* in vario/g matters. Pull while lift increasing, push when lift decreasing.
- No big zoomies, pushovers (safety!)
- In strong persistent lift, slow to < min sink, flaps, S turns. But be ready to push!
- Don’t get caught too slow wishing for it. Slow in sink is worse than fast in lift.
- Leave thermals gently, following clouds, wind, gliders (sorry, Moffat.)
- Course deviations to fly in lift are more important than speed changes. (20 degrees = 6% longer, 30 degrees = 13% longer)
- *Never* cruise best L/D! If you’re not in lift, you’re in sink!
- (Exception: desperate glide in absolutely smooth no / sink air)

MacCready 301. Lower Mc settings.

Why do we use Mc 3-4 in “6-8 kt lift?”

- *Centering time*
- Thermals vary with altitude
- Range / altitude bands
- Feel the air
- Risk, risk aversion

4 kts

7 kts! Call buddies on radio

Drat, lost it, recenter

Glide

6 kts

4 kts

3 kts

Time to center

- *This is not a 7 kt thermal!*
- *Mc = lesser of initial climb,*

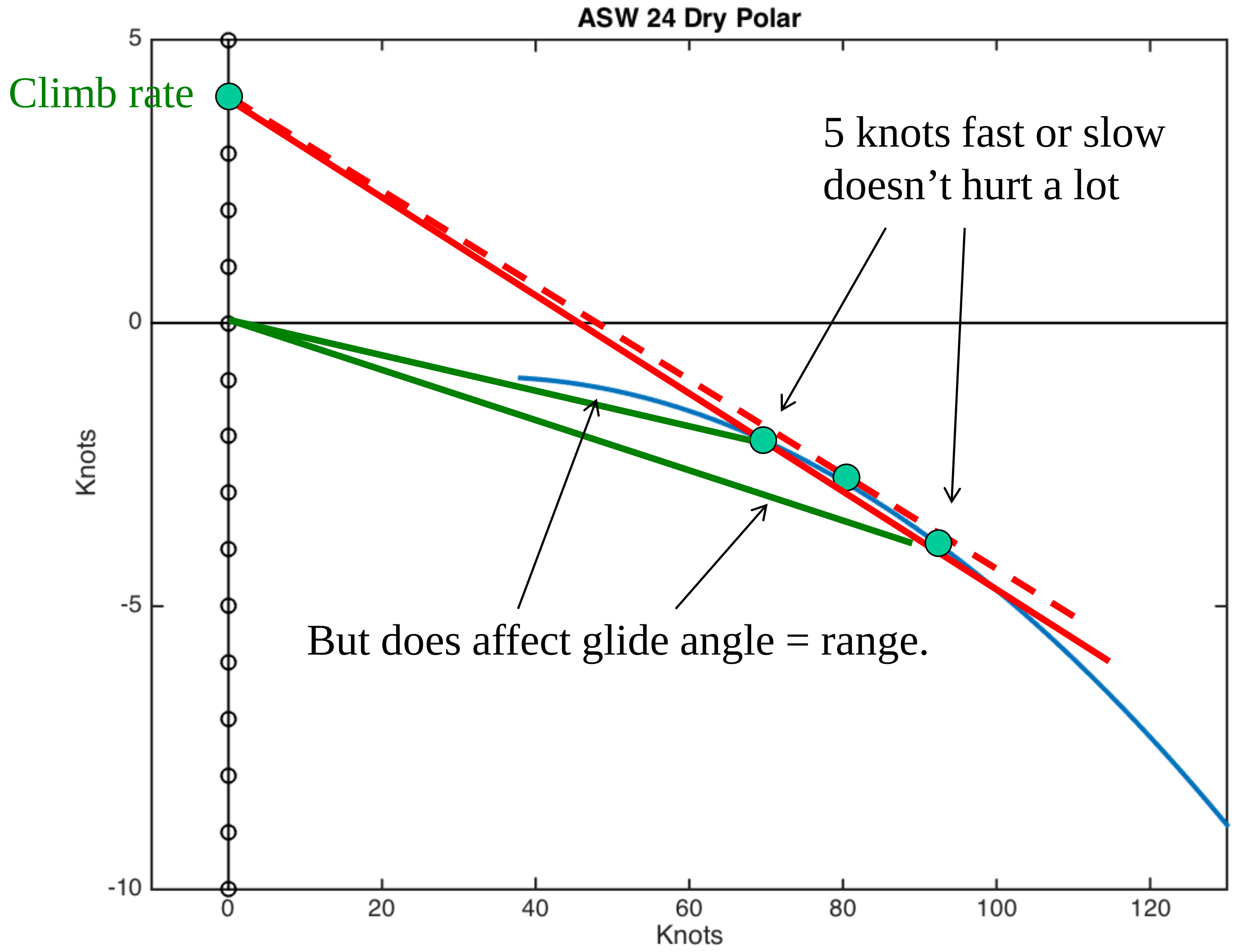
Total bottom to top climb

Mc 301. Lower Mc Settings: Centering time.

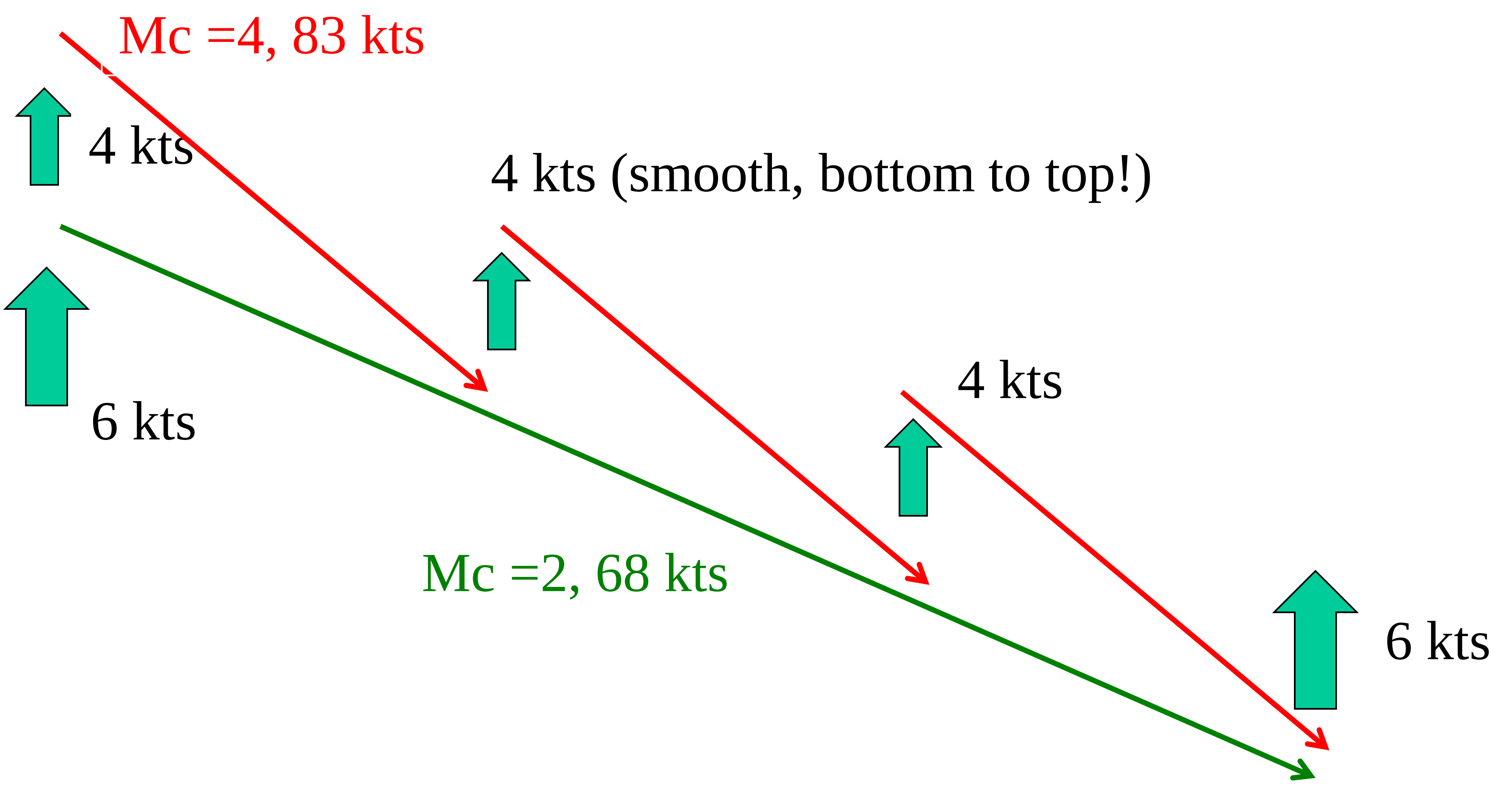
Height Gain	Lift 2.00	4.00	6.00	8.00
	centering time = 0.50			
1000	1.82	3.33	4.62	5.71
2000	1.90	3.64	5.22	6.67
5000	1.96	3.85	5.66	7.41
	centering time = 1.00 (3 circles)			
1000	1.67	2.86	3.75	4.44
2000	1.82	3.33	4.62	5.71
5000	1.92	3.70	5.36	6.90
	centering time = 2.00			
1000	1.43	2.22	2.73	3.08
2000	1.67	2.86	3.75	4.44
5000	1.85	3.45	4.84	6.06

- Again, "8 kts" is not 8 kts! Lower Mc settings *is* Mc theory.
- Worse for strong lift & short climbs
- "Don't climb unless 2000'gain" "Long glide" -- *Unless smooth.*
- Smooth more important than strong for stop to climb decision.
- Worth staying in thermals past peak if still smooth. You paid entrance fee.
- Instruments: Bottom to now averager! (See you trace) Compare 20 sec / bottom to now.

MacCready 301: Range



A Common Range Fallacy



Take smooth, or bottom to top lift greater than your glide Mc setting.

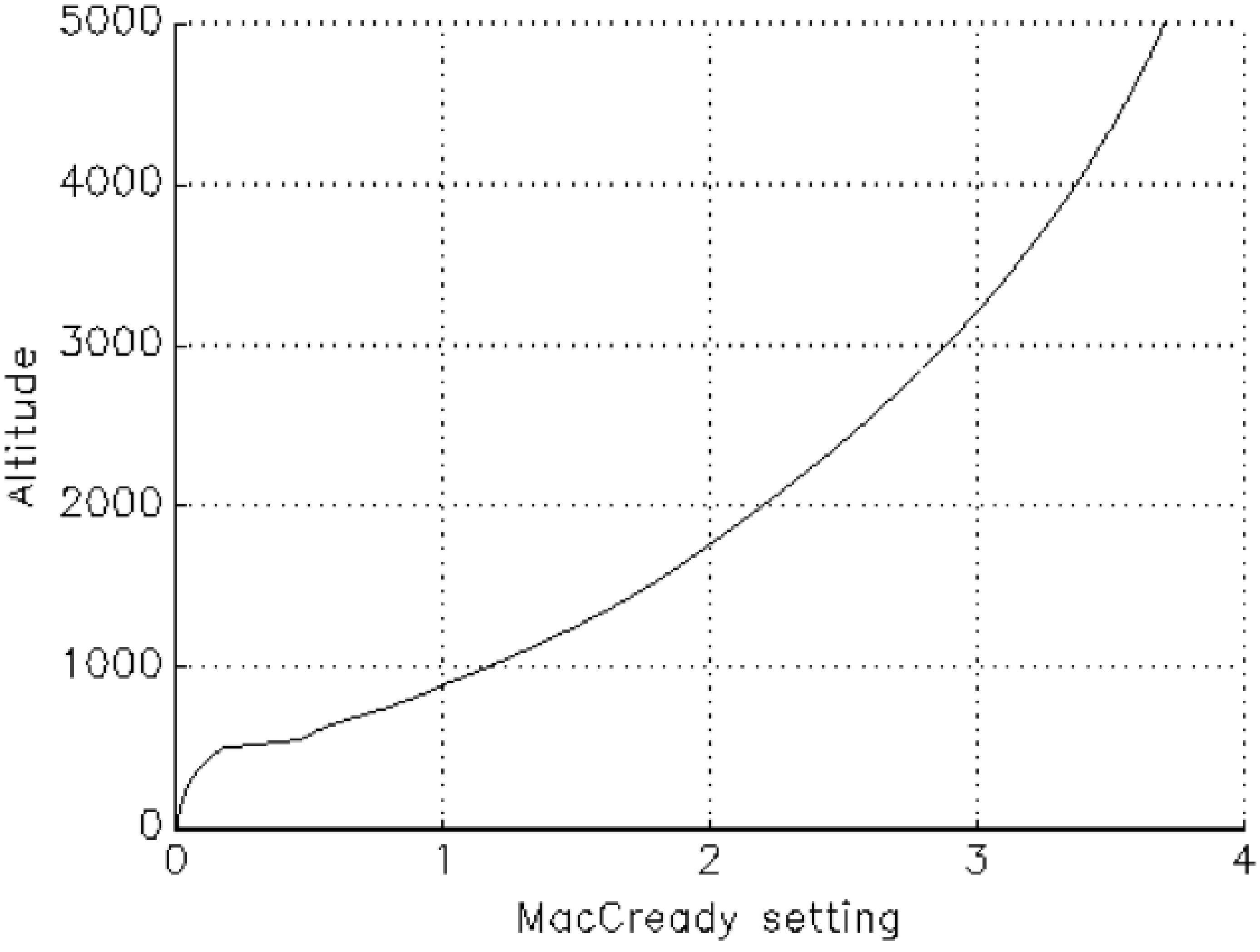
Full optimum: A simple calculation

- Math: find the best speed, but add :
  a. Altitude > 0,
  b. Landout valued by US rules.
  c. Thermals are random:

Thermal Strength	Miles 1	5	10
1	20	90	99
2	10	61	84
4	5	30	52
6	2	10	18

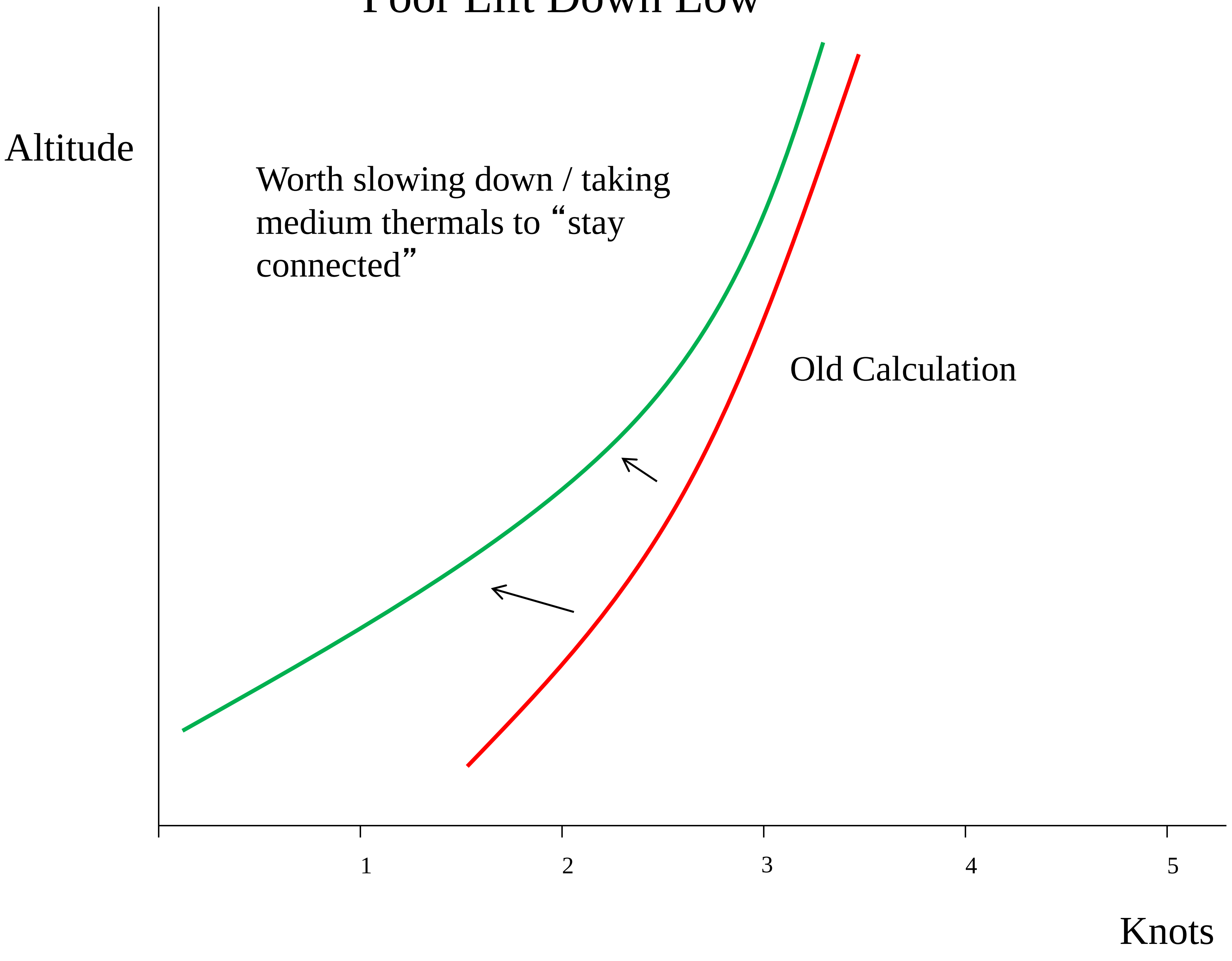
Probability (%) of finding a thermal at least this strong

(Discus flying in Northern Illinois on a good day)



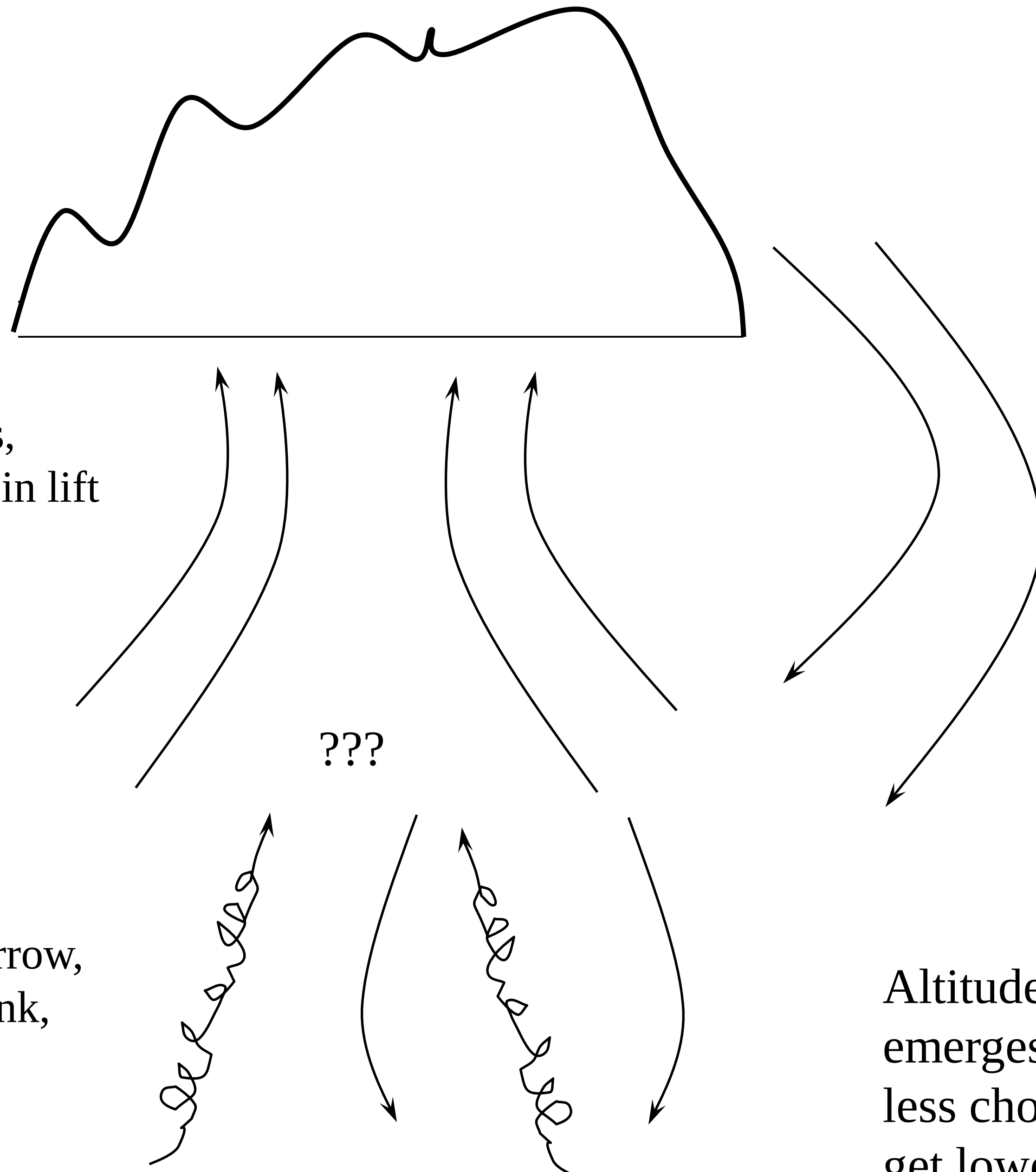
- This is the "weakest thermal you'd take = lift to leave."
- Steadily change setting with height. Stairstep saves.
- "4-6 knot day". Settings are a lot lower! "Don't fly Mc?"
- A flexible "height band" *emerges*.

Poor Lift Down Low



“Stay High”

Large smooth thermals,
Easy to do long glides in lift



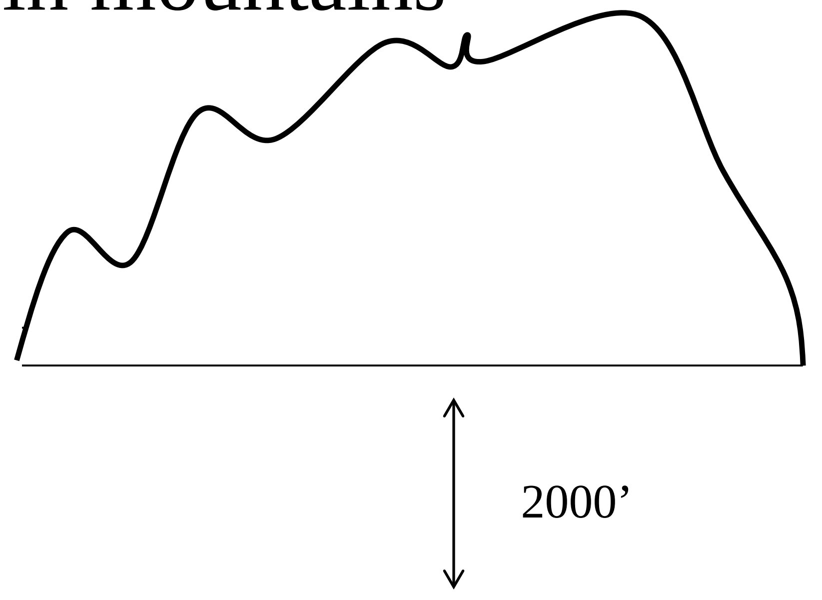
Mc 5

Mc 3

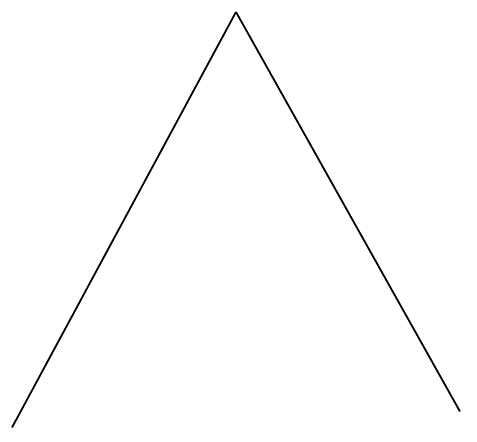
Strong thermals, but narrow,
hard to center, lots of sink,
Don’t match clouds

Altitude band
emerges by being
less choosey as you
get lower

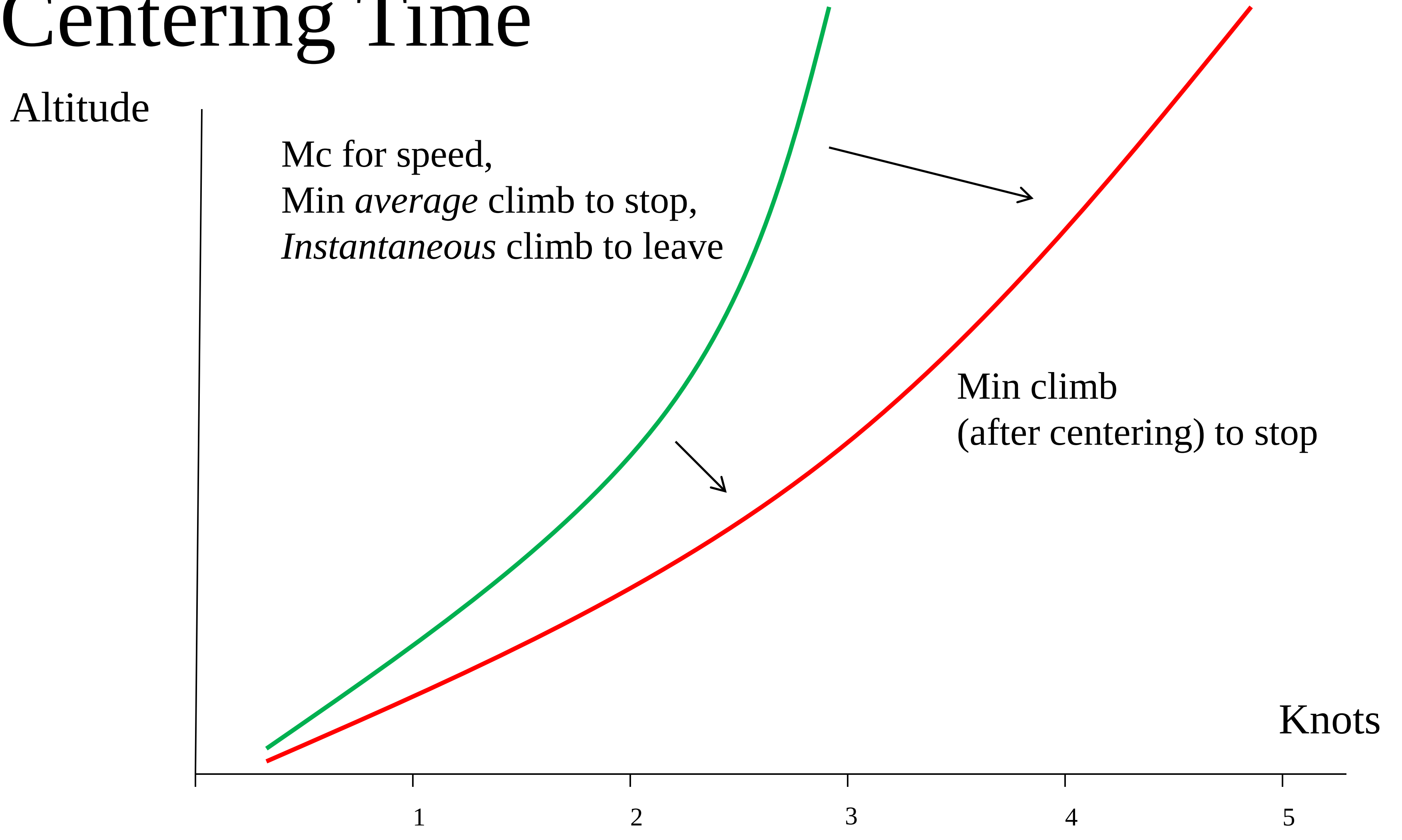
“Stay High” in mountains



Crucial question: What’s it like here?

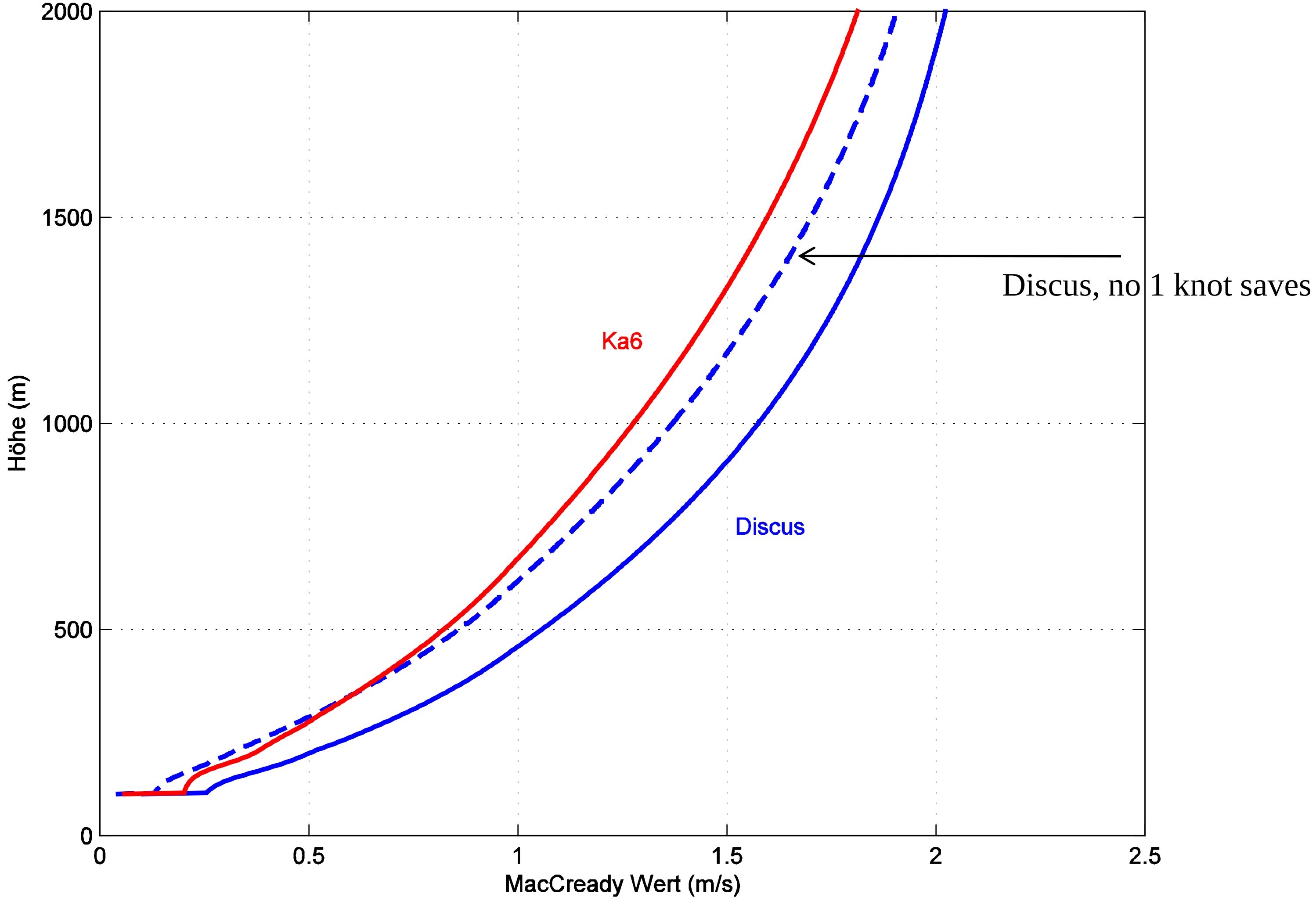


Centering Time



- Stay in weaker lift than you'd stop for, cruise at "stay" value
- How long it will take to center? Decides if you stop!

Glider/pilot performance



- Slower pilots, gliders need to fly more conservatively.
- Less chance of 1 knot saves = fly a discus like a Ka6

Higher/lower Mc values

Lower:

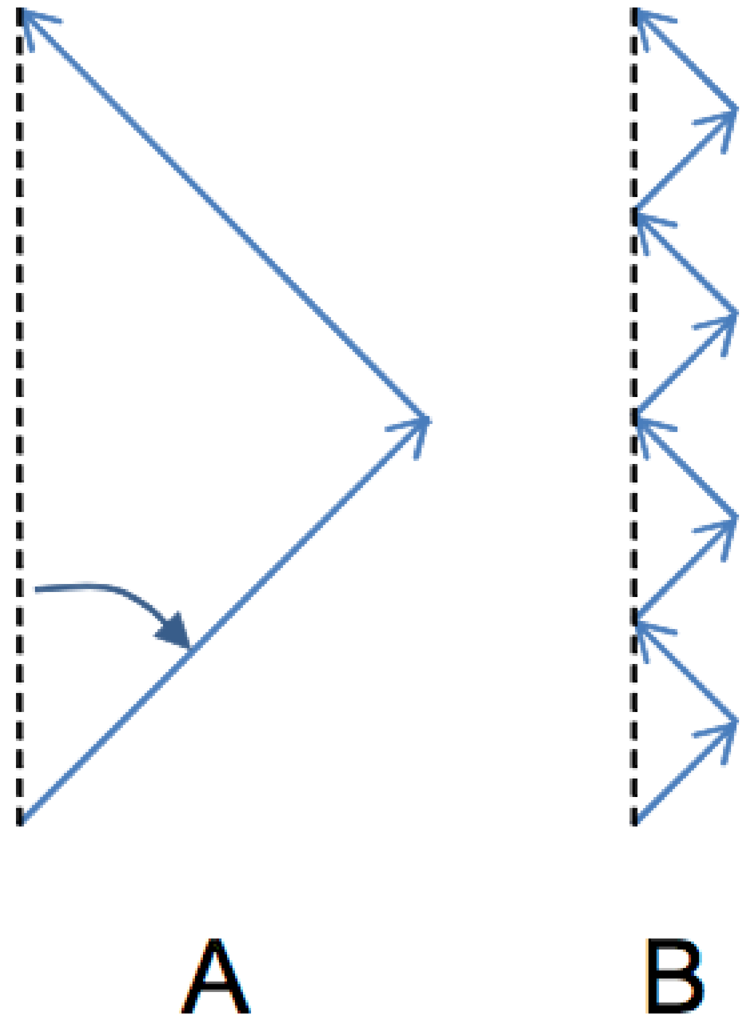
- Centering time
- Initial/final climb. Mc = min(bottom to top, initial)
- Feel the air.
- Risk aversion. Greater landout costs. Harder low saves.
- Mc now = expected Mc ahead. But expected min / foot. Average of 1, 3, 5 is 1.6 – lower settings! (average of 1/1, 1/3, 1/5 is 1/1.6)

Higher:

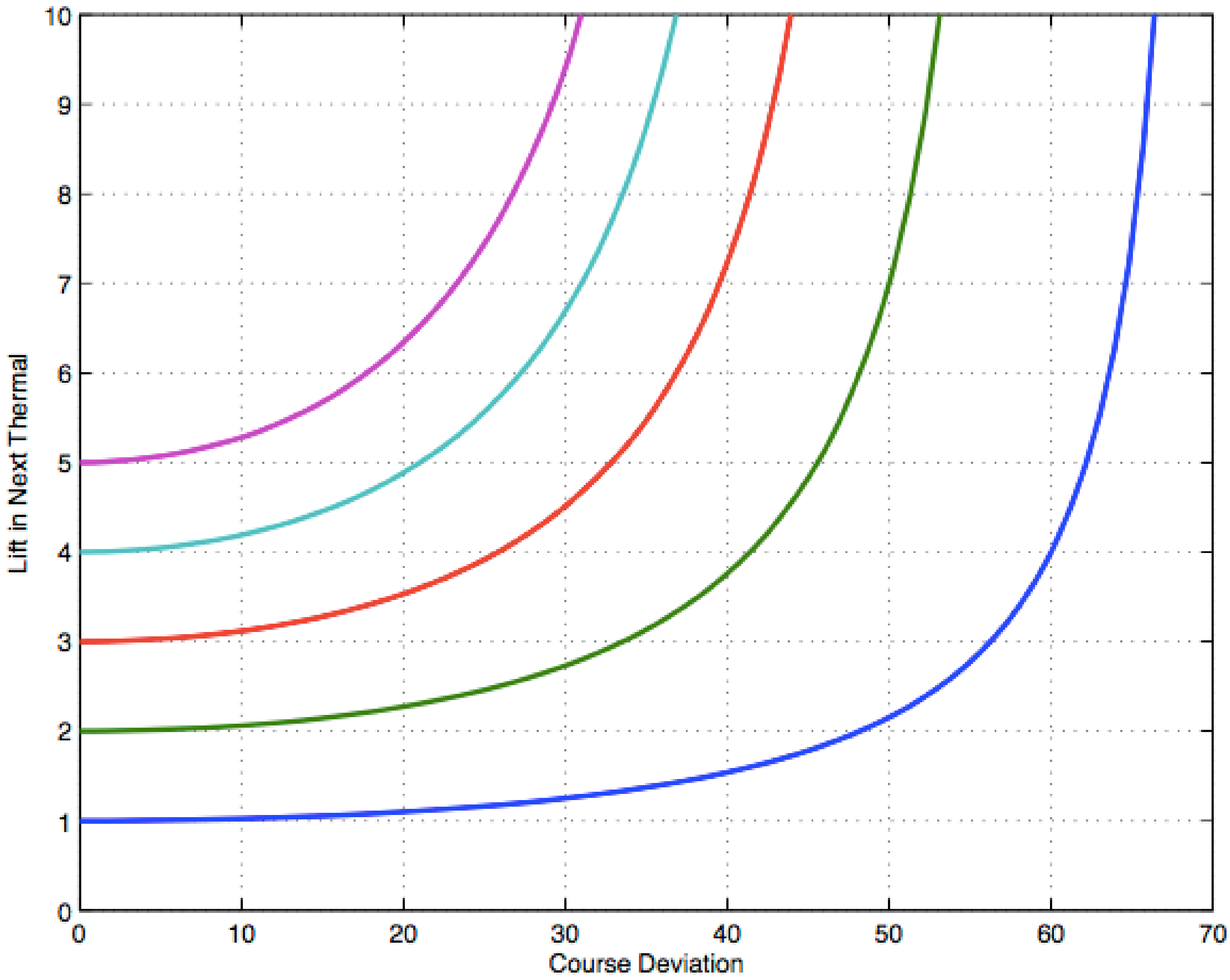
- See teammate ahead, good gaggle.
- "Race MacCready" – with a group whose expected climb is better than individual one, or whose expected altitude at climb is better.
- Objective: Win, not max expected speed. (Gamble.) SGP!

Bottom line: Fashion for long slow glide is giving way to higher speeds in racing – when appropriate

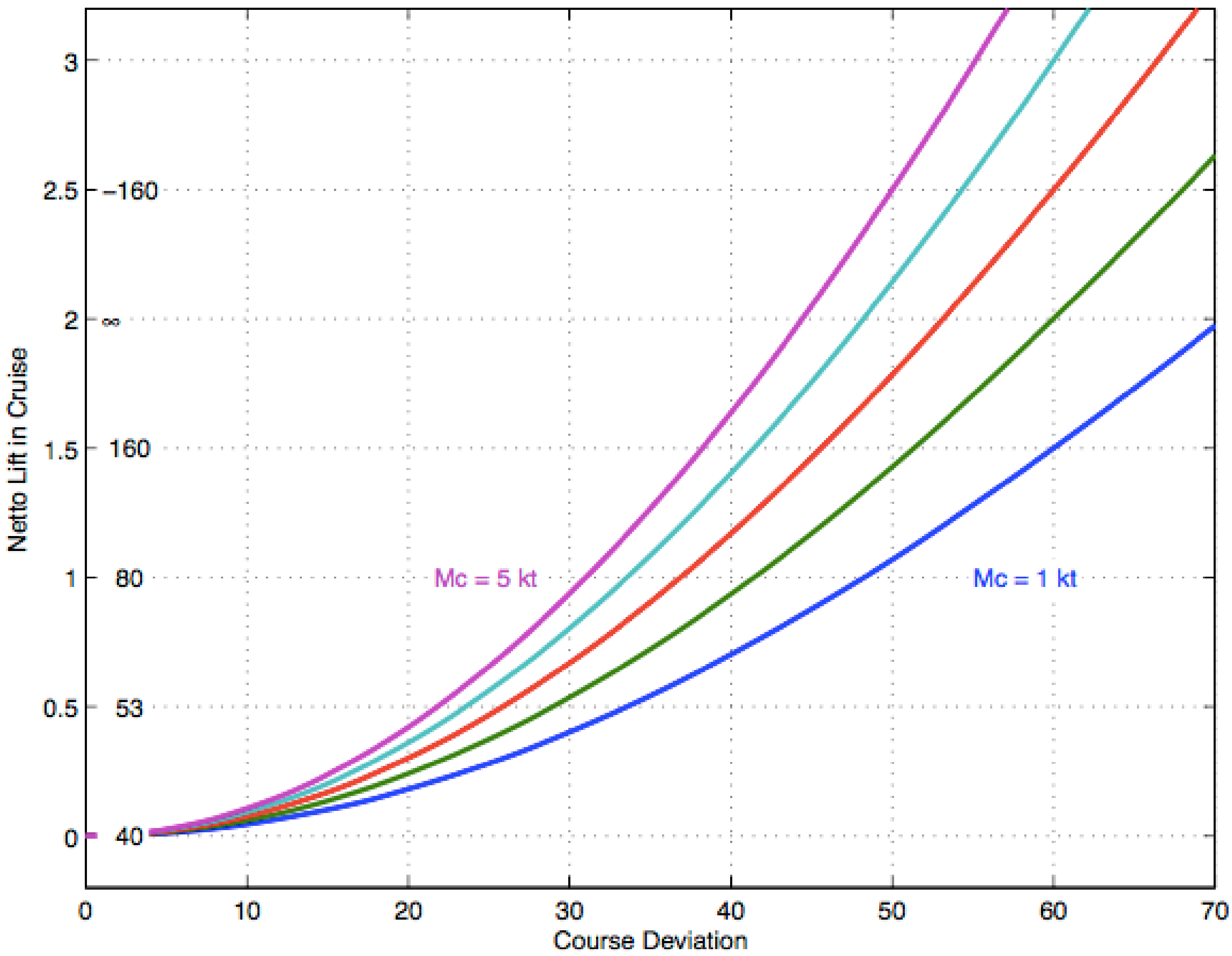
Course deviations – degrees matter not distance



Course deviations – how far to get a better thermal?

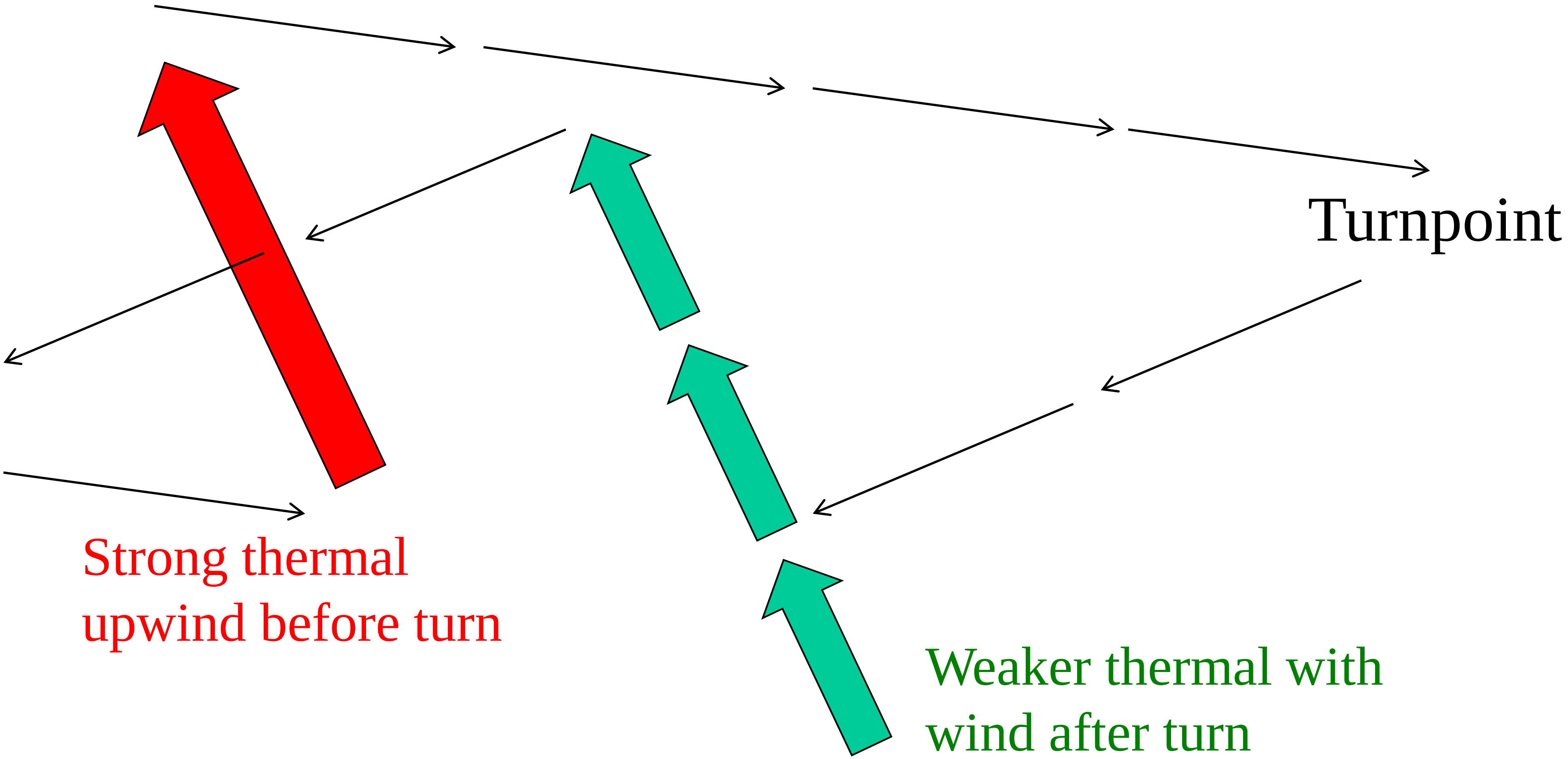


Course deviations – to cruse in lift/avoid sink



Upwind/downwind

X knots upwind = Y knots downwind. Y << X. How much?



MacReady values around a turnpoint with wind

How *much* is 2 knots downwind really =, upwind?

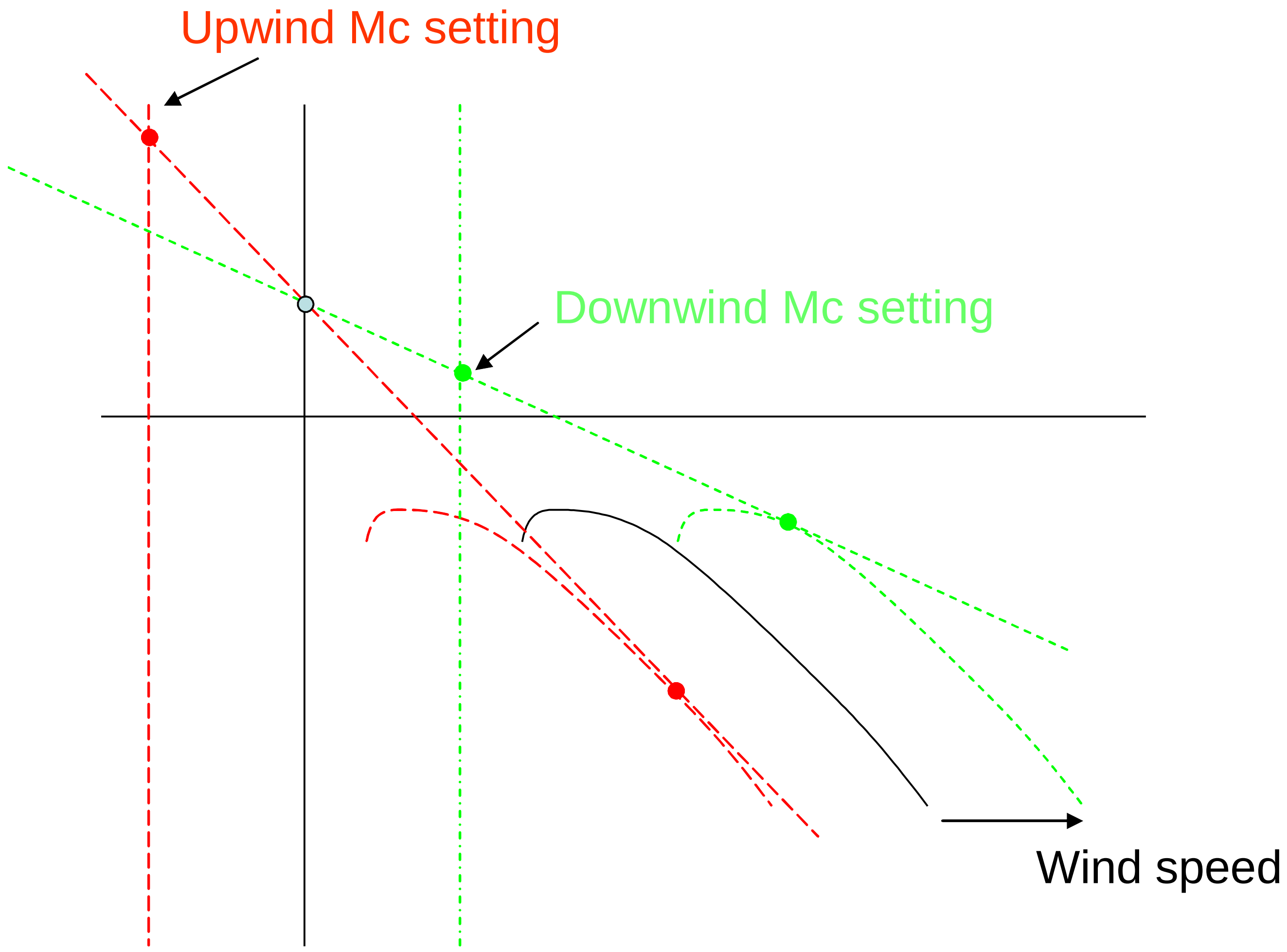


Table of upwind / downwind turnpoint MacCready values.

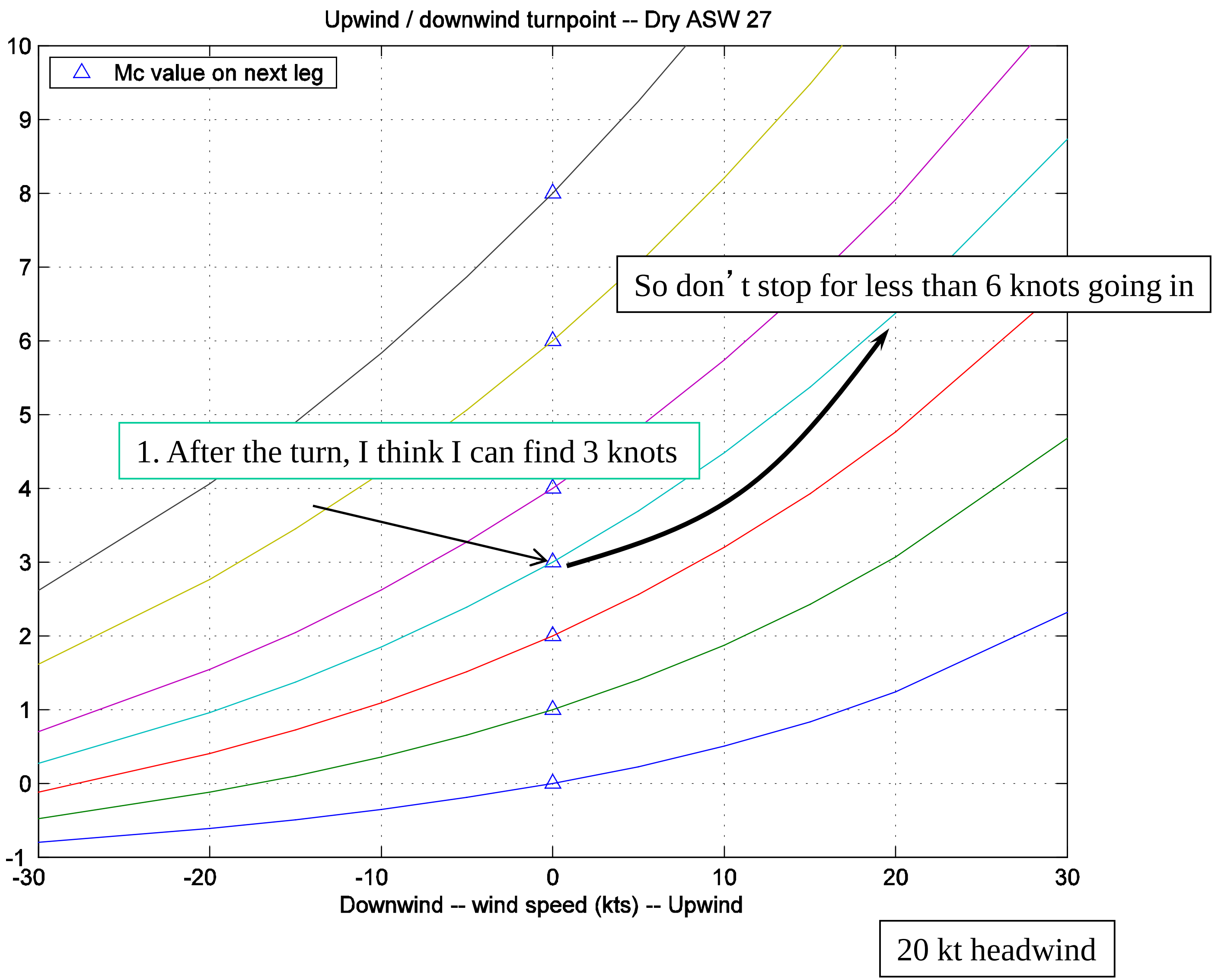
Dry ASW 24

Use this on the ground at the beginning of the day!

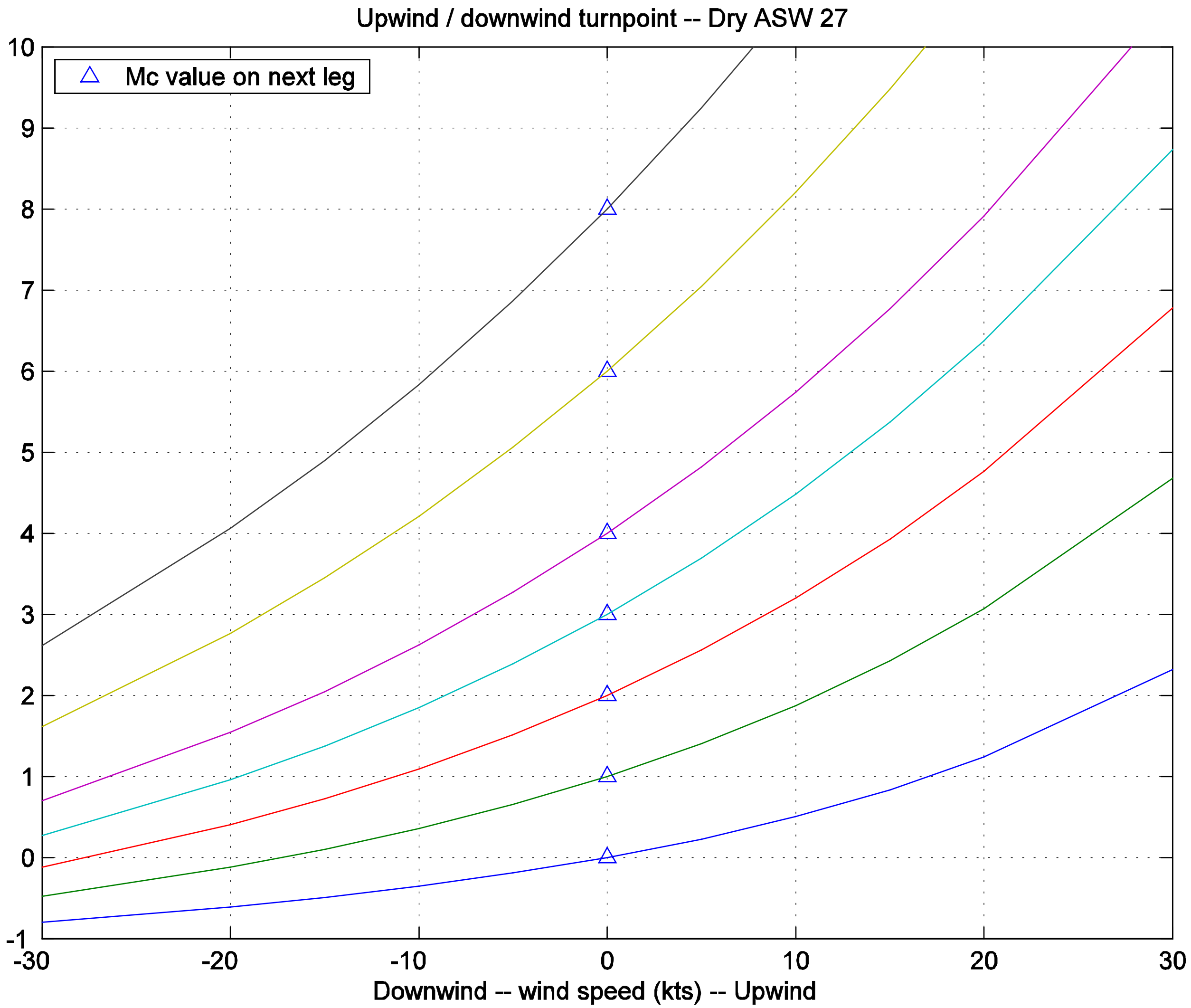
Wind (kts)

-30	-20	-15	-10	-5	0	5	10	15	20	30
-0.8	-0.6	-0.5	-0.4	-0.2	-0.0	0.3	0.6	1.0	1.5	2.8
-0.6	-0.2	0.0	0.3	0.6	1.0	1.5	2.0	2.7	3.4	5.2
-0.3	0.3	0.6	1.0	1.5	2.0	2.6	3.4	4.2	5.1	7.4
0.1	0.8	1.2	1.7	2.3	3.0	3.8	4.6	5.6	6.7	9.3
0.5	1.3	1.9	2.5	3.2	4.0	4.9	5.9	7.0	8.3	11.2
1.3	2.5	3.3	4.1	5.0	6.0	7.1	8.4	9.7	11.2	14.6
2.3	3.8	4.7	5.7	6.8	8.0	9.3	10.8	12.3	14.0	17.9

- Use glide computer to see altitude at turnpoint.
- If at that altitude and weather you'd take 3 knot thermals,
    - Upwind 15 knots – don't stop for less than 5.6 and glide that fast
    - Downwind 15 knots – take anything more than 1.2 knots and fly that slow.
- You will likely end up high at downwind, low at upwind turnpoints.

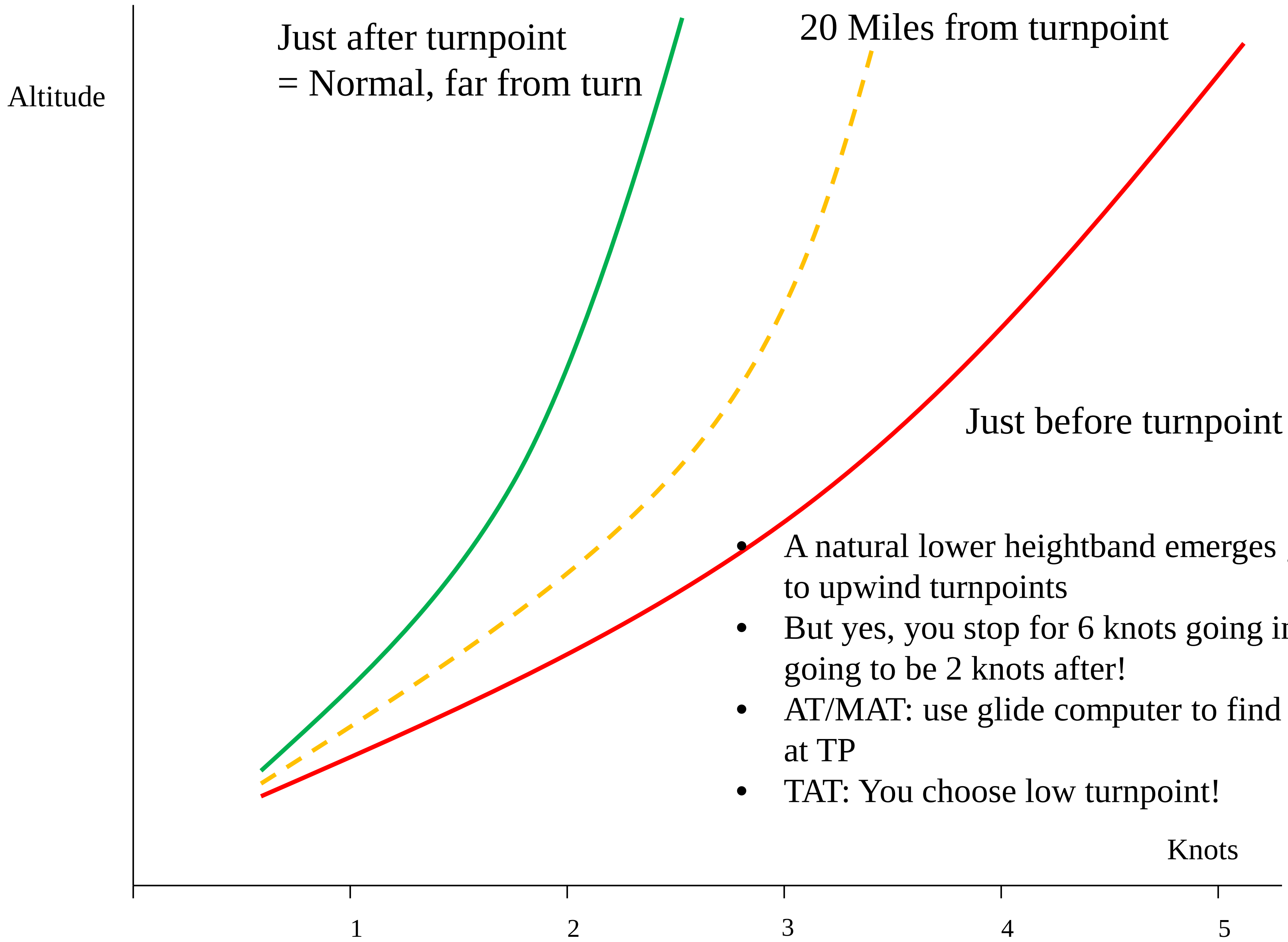


Set glide solution to turnpoint. Consider Mc (altitude) at turnpoint. AAT: You choose turnpoint!



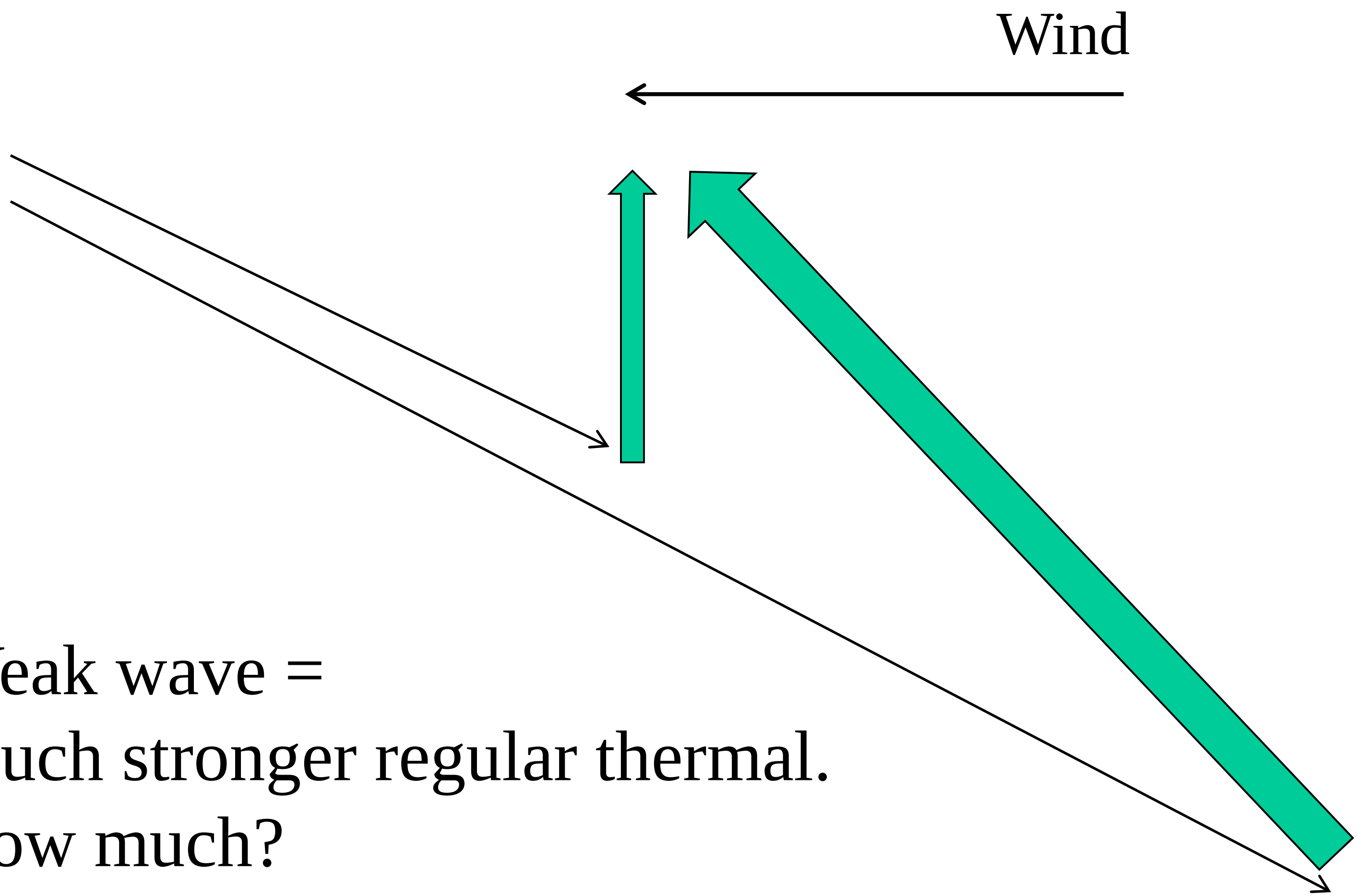
Upwind / downwind turnpoint -- Dry ASW 27
Mc value on next leg
10
9
8
7
6
5
4
3
2
1
0
-1
-30
-20
-10
0
10
20
30
Downwind -- wind speed (kts) -- Upwind

An Upwind Turnpoint



- A natural lower heightband emerges going in to upwind turnpoints
- But yes, you stop for 6 knots going in if it's going to be 2 knots after!
- AT/MAT: use glide computer to find altitude at TP
- TAT: You choose low turnpoint!

MacCready in wave (yes)



Weak wave =
Much stronger regular thermal.
How much?

MacCready in Wave.
Headwind is like a slower glider

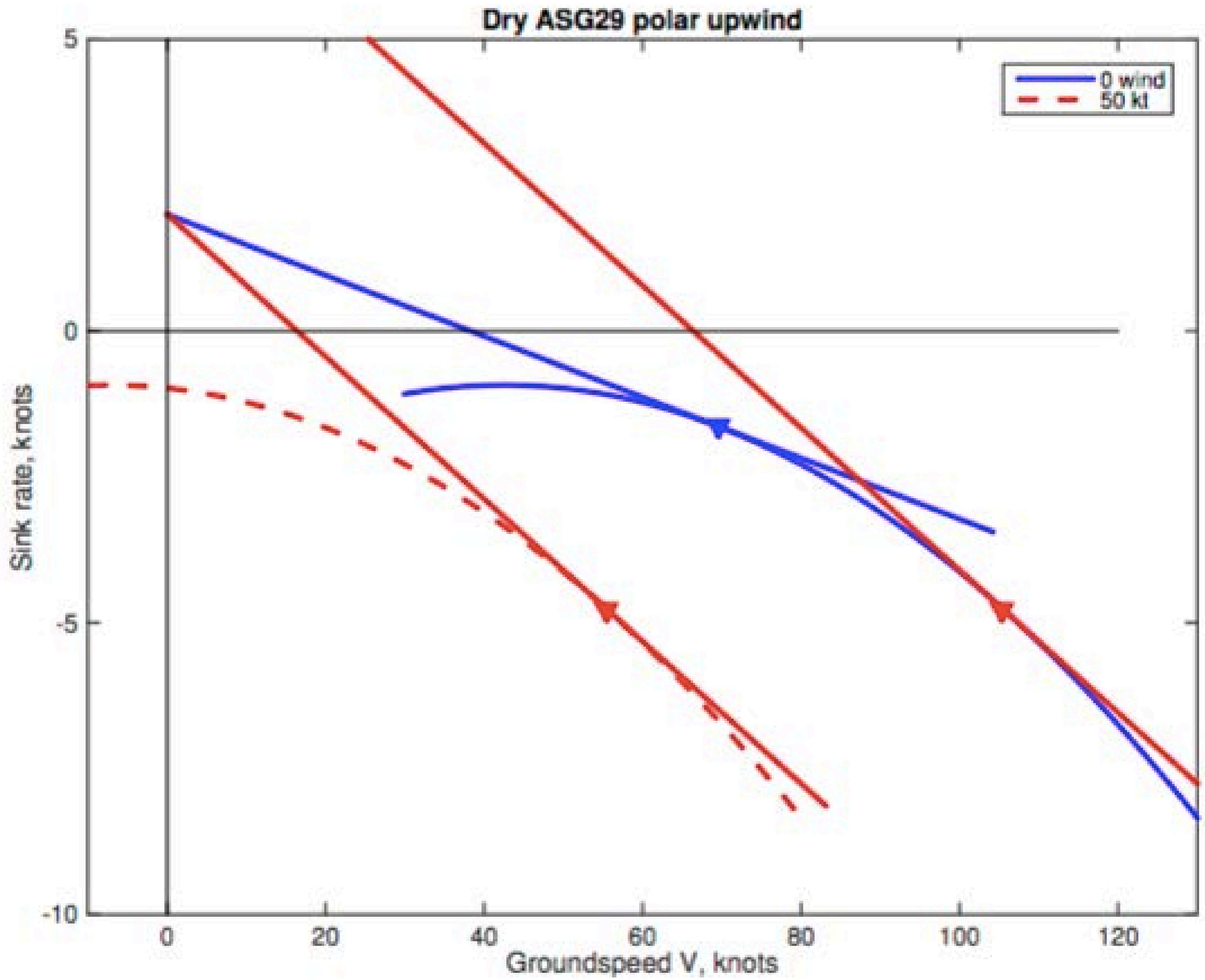


Table 1: Speeds to fly and Mc settings to fly upwind to wave lift

Upwind Speed to fly

	Dry				Wet			
	Wind speed				Wind speed			
Lift	0	20	40	60	0	20	40	60
2.0	69	79	95	118	88	97	111	130
4.0	83	95	111	133	104	115	130	149
6.0	95	107	125	146	117	130	146	165

Upwind Mc setting

	Dry				Wet			
	Wind speed				Wind speed			
Lift	0	20	40	60	0	20	40	60
2.0	2.0	3.4	6.1	10.7	2.0	3.2	5.1	8.1
4.0	4.0	6.0	9.3	14.6	4.0	5.6	8.0	11.6
6.0	6.0	8.5	12.4	18.1	6.0	8.0	10.9	14.8

Crosswind Speed to fly

	Dry				Wet			
	Wind speed				Wind speed			
Lift	0	20	40	60	0	20	40	60
2.0	69	72	79	94	88	90	96	106
4.0	83	85	93	106	104	106	111	122
6.0	95	97	104	116	117	119	125	135

Crosswind Mc Setting

	Dry				Wet			
	Wind speed				Wind speed			
Lift	0	20	40	60	0	20	40	60
2.0	2.0	2.3	3.4	5.8	2.0	2.2	2.9	4.4
4.0	4.0	4.4	5.7	8.2	4.0	4.3	5.1	6.7
6.0	6.0	6.4	7.8	10.4	6.0	6.3	7.2	8.9

Bottom line

- At any moment, weather, wind, altitude, etc. determine MacCready value – if I were x feet higher I could arrive 1 minute sooner.
- This governs all soaring decisions – time vs. altitude.
- Take any (smooth, bottom to top) lift greater than Mc Value (and Mc Value is weakest lift you'd take).
- Leave any lift below Mc Value. Now.
- Do not fly slower than Mc Value.
- Mc value determines size of course deviations.
- Slowly adapt speed to persistent predictable lift and sink
- Choose it right! And change fast as weather changes.
- Use substantially higher Mc values in your glide computer for safety – 4 – 6 minimum.
- Climb better! Locate, enter faster, be quicker to leave bad lift.
- Climb better!

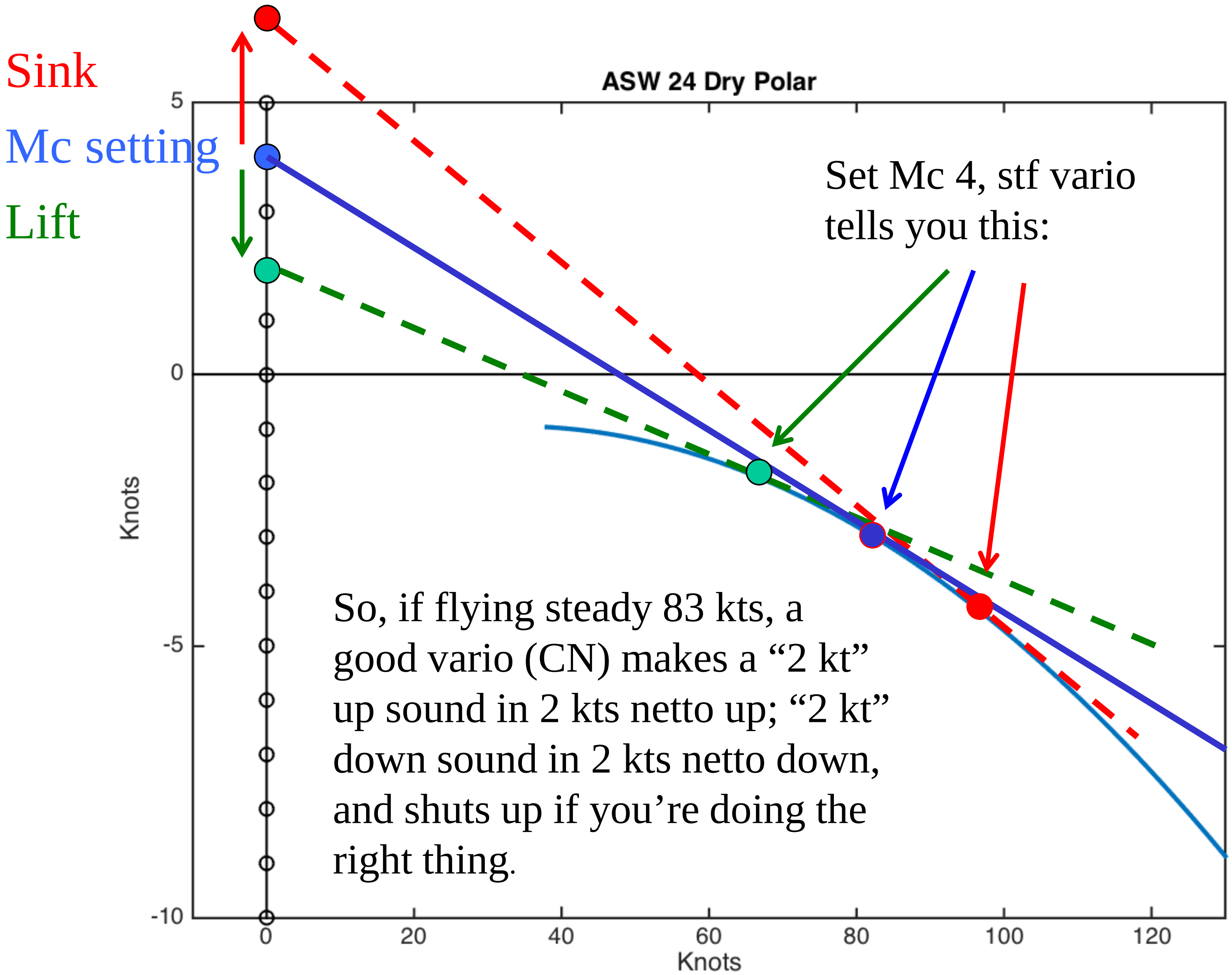
More

MacCready and other theory of how to fly contests

- MacCready Theory in Wave. November 2016. How to apply MacCready theory in wave. Fly faster. Matlab program
- Safety glides. (Later published in Soaring) February 27 2012 How to use your glide computer for safety glides. Don't use Mc 0 and expect to get home. The square root rule, and more. Slightly expanded version with metric units: (pdf) or (doc) (August 2012)
- Deviations Part I Sept 2011. (Later published in Soaring) How far off course should you go to chase that juicy cloud? The MacCready theory of course deviations. (Part I is the case with no wind. Part II with wind on the way.) This version includes the algebra appendix for masochists.
- Just a little Faster Please Jan 2007. Condensed and rewrote the article for publication in Germany. This version is better, except the numbers are all m/s and km. Slovenian translation. German version.
- Just a Little Faster Please July 2000. Article for Soaring Magazine on applying new MacCready theory.
- Flying Faster Part 2
- Upwind and downwind The theory of upwind and downwind turnpoints. Oct 2006 (Also a "contest corner"
- "MacCready Theory with Uncertain Lift and Limited Altitude" *Technical Soaring* 23 (3) (July 1999) 88-96. This version cleans up some typos that crept into the published version. Acrobat 3.0 pdf file Programs contains matlab and gauss programs for making the calculations.
- NOTE: Robert Almgren wrote this very nice and mathematically much better version of the theory. Even if you don't like equations, skip to Figure 4.1 and 4.2 which are full of insights.
- "The start time game in competition soaring" *Technical Soaring* 22 (2) (April 1998) 56-64 . This article analyzes when to start early, when to start late, when a big gaggle will form, and so on. Acrobat 3.0 pdf file.

Google “John cochrane soaring” or http://faculty.chicagobooth.edu/john.Cochrane/soaring/index.htm

Understanding the instruments



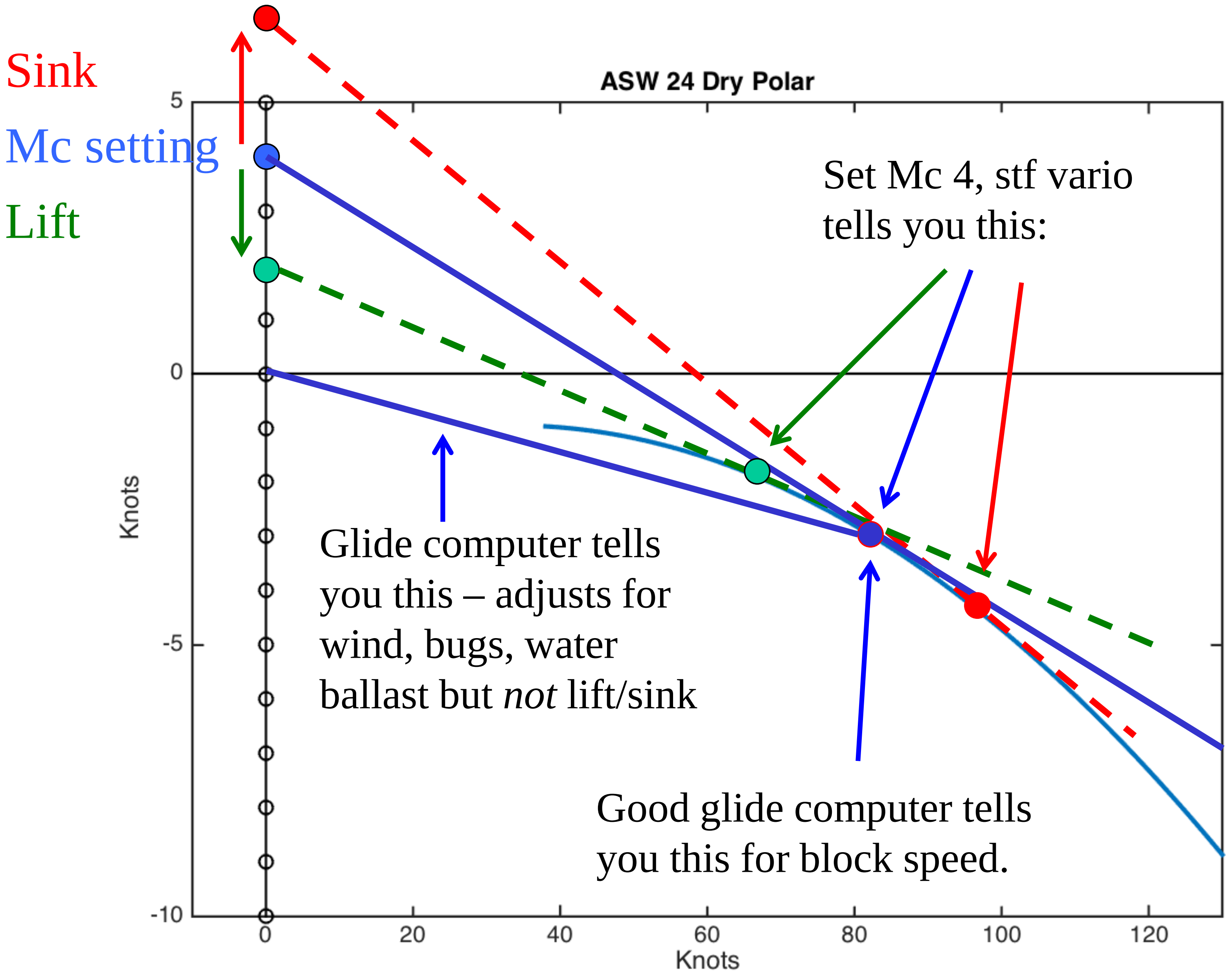
Set Mc 4, stf vario tells you this:

So, if flying steady 83 kts, a good vario (CN) makes a “2 kt” up sound in 2 kts netto up; “2 kt” down sound in 2 kts netto down, and shuts up if you’re doing the right thing.

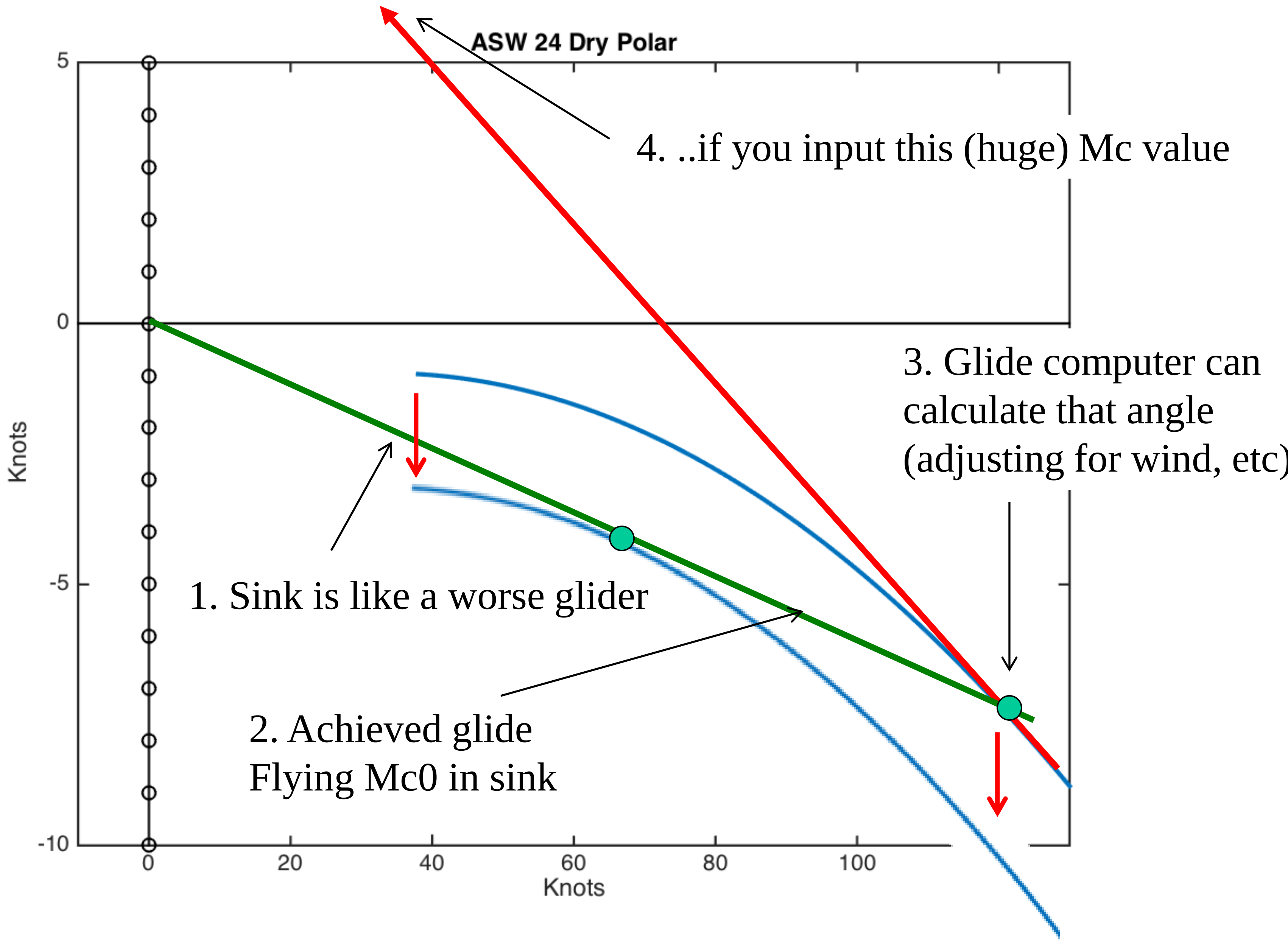
Practical dolphin flying – Instruments (Warning: opinions vary)

- Vario: A fast well compensated speed-to-fly audio is essential. Don't follow push pull, use it to listen to air, push pull slowly.
- Netto is acceptable, but leads to milking bad lift, not flying fast enough. Use stf audio as netto instead.
- Regular vario: Next to impossible.
- Examples: 1) Mc 3 + 1 kt sink, 85kts. Vario = -4.5. Find 1 kt lift? Vario = -2.5. Slow down? 2) 1 kt sink. Same annoying tone for Mc 1, 4; water/none; flying fast/slow/right.
- My vario in cruise:
  - Audio: Fast STF, no deadband (what's the air doing?)
  - Needle: Relative (how fast would I climb if I stopped now?)
  - Averager: slow netto (used rarely)
- In climb:
  - Audio: Fast regular. Needle slower (rarely used)
  - 20 sec average, bottom to top average (important)

Understanding the instruments



Using Mc for safety glides



Using Mc for safety glides

Dry ASW 24

Mc (kts)	Glide (kts)	L/D	D/L ft/mi	- Avg Speed- (mph)	(kph)
0	47	42	125	0	0
1	58	39	134	27	44
2	68	35	152	39	63
3	76	30	173	48	77
4	83	27	195	54	87
5	90	24	216	60	96
6	97	22	237	65	104
7	102	20	258	69	111
8	108	19	278	73	117

To Calculate 24:1 / 216'/mi safety glide (adjusted for wind), input ***Mc 5*** to glide computer. For French Alps 20:1, ***Mc 7.***

Effect of airmass sink on glide – max glide; flying Mc 0

Sink (kts)	Glide (kts)	L/D	D/L ft/mi	Mc	Vario (kts)
0.0	47	42	125	0.0	1.1
0.5	53	30	177	3.2	1.8
1.0	58	24	225	5.4	2.5
1.5	63	20	268	7.5	3.2
2.0	68	17	308	9.6	4.0
3.0	76	14	382	13.7	5.5
4.0	83	12	448	17.7	7.1
5.0	90	10	509	21.7	8.7

Steady 1 knot sink, flown optimally (58 knots) at Mc 0, gives you a 24:1 glide! Same as Mc 5 in still air!

Using Mc, glide computer, for safety glides

- Decouple glide computer, speed director.

- Use much higher Mc for safety considerations than speed.
    - Speed: average thermals ahead. Safety in lower Mc values
    - Glides: worst case sink ahead. Safety in higher Mc values
    - Good weather is more dangerous! No lift = no sink.

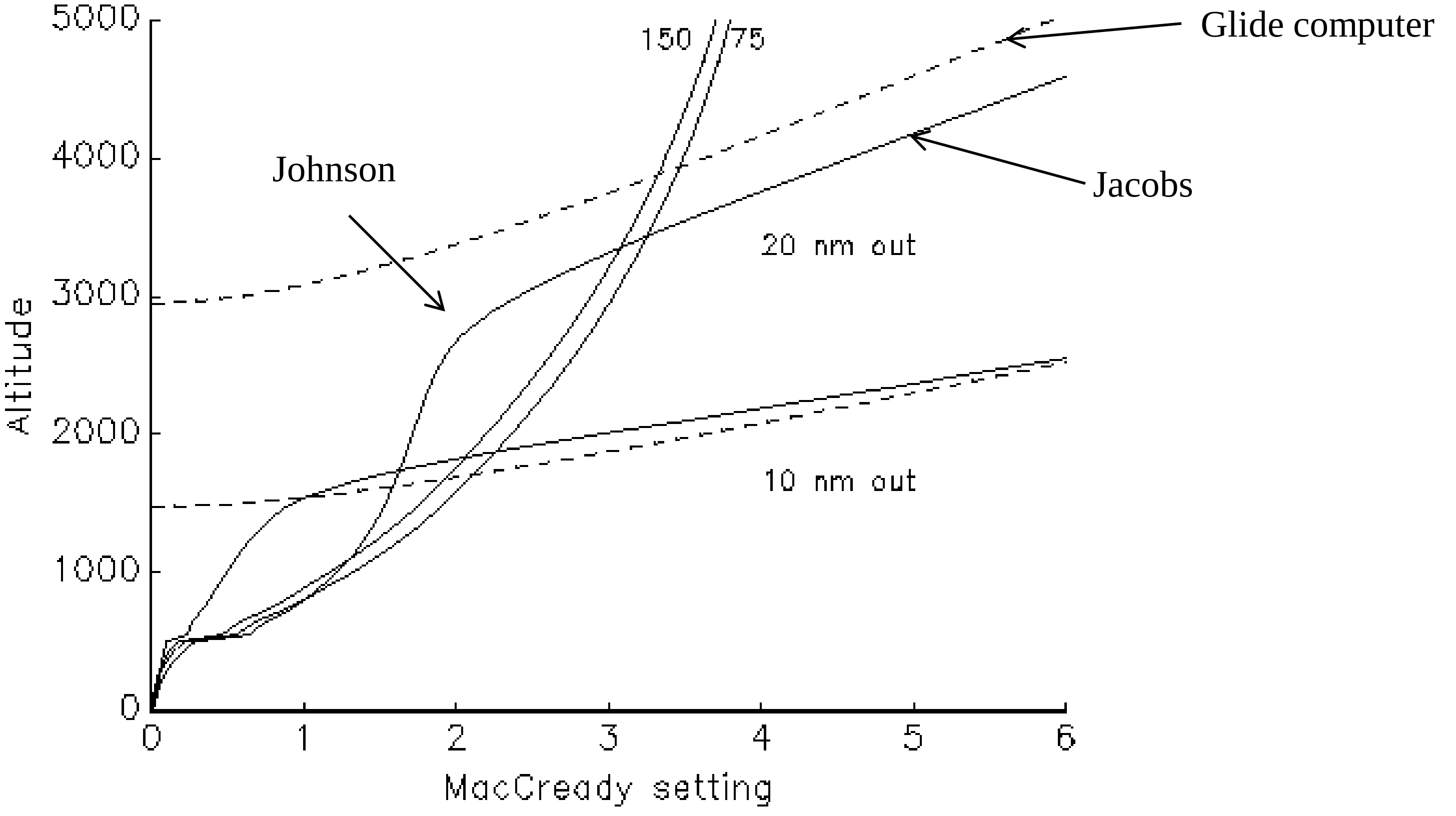
- Rules of thumb:
    - Mc 3, 30:1: Contests, over safe fields.
    - Mc 4-5: 25:1 Everyday flying, safe but inconvenient options.
    - Mc 6-7: 20:1 Bad options or wave etc. persistent sink.
    - More: your life depends on it, and wave etc. sink around.

- Fancy version: Sink doesn’t last forever, so longer glide angles are safer. Thus, combine glide angle + arrival height. Further: Less glide, more height. Closer: Steeper glide, less margin.

- Williams summertime special case. No lift or sink in the valley on summer days (only), so Mc 1 + 1000’. This is a special case, don’t use it elsewhere!

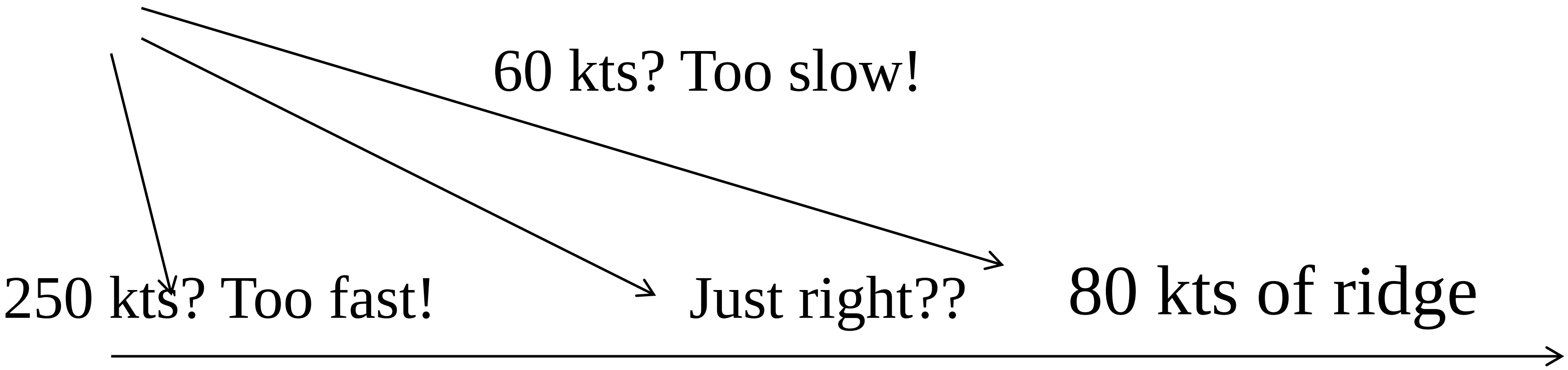
Final glides

- Jacobs: start low, bump up.
- Johnson: stay high, 10 extra points not worth a landout catastrophe



- Start like Jacobs, finish like Johnson
- Depends very much on lift down low – and fields in the last few miles
- Take heart ye chickens: Taking strong lift and finishing fast works!

How fast to glide to a ridge?



Answer: Find Mc Setting that produces an average speed of 80 knots. Fly that Mc setting. (Huge)

MacCready Math

- Notation: T_g = time to glide 1 mile. T_c time to climb. V_g = glide speed. V_a = average speed. $S(V_g)$ = sink rate. h = height. M = climb rate (Mc setting).
- Why is V_a where it is on the graph?

$$\frac{1}{V_a} = T_g + T_c = \frac{1}{V_g} + \frac{h}{M} = \frac{1}{V_g} + \frac{T_g S}{M} = \frac{1}{V_g} + \frac{S}{V_g M} = \frac{1}{V_g}\left(1 + \frac{S}{M}\right)$$

$$\frac{V_g}{V_a} = \frac{M+S}{M}$$

- McReady speed derivation:

$$\min_{\{V_g\}} \frac{1}{V_a} = T_g + T_c = \frac{1}{V_g}\left(1 + \frac{S(V_g)}{M}\right)$$

$$-\frac{1}{V_g^2}\left(1 + \frac{S(V_g)}{M}\right) + \frac{1}{V_g}\left(\frac{S'(V_g)}{M}\right) = 0$$

$$\frac{1}{V_g}\left(1 + \frac{S(V_g)}{M}\right) = \left(\frac{S'(V_g)}{M}\right)$$

$$M + S(V_g) = V_g S'(V_g)$$