

Going Faster Makes the Wind Stronger, Which Is Why a Sailing Craft Can Outrun the Wind

— dead downwind the apparent wind reaches **0** the instant the boat matches the wind — across the wind, a boat doing **50 m/s** feels **50.9902 m/s** — same wind, same sail: one is capped and the other is not — [Paper 390]

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— *From thinking to syncing.* —

Abstract

A sail is pushed by the wind, so a boat cannot outrun the wind——so it seems. This paper shows that changing only the heading removes the cap——neither the wind nor the sail is altered at all. No new theorem or law is claimed. First, dead downwind, the apparent wind reaches **0.000000 m/s** the instant the boat matches the **10 m/s** wind (Section 2). Second, across the wind, a boat doing **10 m/s** still feels **14.1421 m/s** (Section 2). Third, and this is the core of the paper. At **50 m/s** the apparent wind is **50.9902 m/s**——stronger the faster you go, with no ceiling (Section 2). Fourth, the ceiling is set by the sum of the drag angles of sail and craft, giving **4.4444** for an ice boat (Section 3). Fifth, improving the sail alone is not enough: the formula is symmetric in sail and craft (Section 3). Sixth, the separator is whether the heading is parallel to the true wind or not (Section 5).

Scope of this paper (scope note): No new theorem or law is claimed——apparent wind, propulsion by lift and the drag-angle speed limit are all known in yacht engineering.No craft is designed——sail plan, trim and hull form are not given. Only the velocity triangle and the drag angles are examined.No fluid dynamics is built——the generation of lift and stall are not entered. Lift-to-drag ratios are treated as given numbers.Waves and the sea surface are not treated——wave resistance, planing and sea state are not the subject. This is why an ice boat sits closer to the formula.Wind structure is not treated——the vertical wind profile and turbulence are not the subject; the wind is taken as uniform.No record is claimed——whether any particular speed record stands is not the subject.Relation to earlier papers: Paper 387 showed that when to leave is decided outside the place——here the presence of a cap is decided by the heading.Paper 384 showed that the frequency term of free-space loss comes from the receiving side——here the apparent wind comes from one’s own speed.Paper 357 showed that maximum power and maximum efficiency are different points——here the balance of thrust and drag sets the ceiling.Paper 300 showed that same-root and different-root can be decided——true wind and apparent wind are different-root by that criterion.What is added is putting numbers on the apparent wind at six boat speeds, showing that the cap is present downwind and absent across the wind, obtaining 50.9902 m/s at 50 m/s, confirming the 4.4444 ceiling and the symmetry of the formula, and placing the separator at “parallel to the true wind”.

1. Notation and the Question

Setting: let the true wind be $V_t = 10$ m/s. At boat speed V_b , the wind the boat feels is the true wind combined with its own motion.

$$\text{dead downwind : } W_a = |V_t - V_b|, \quad \text{across the wind : } W_a = \sqrt{V_t^2 + V_b^2}$$

Observation 1.1

the left expression is a difference, the right a sum of squares.Only the heading differs——from the same two quantities, entirely different behaviour.

Observation 1.2

a difference can be zero.When $V_b = V_t$ ——a sum of squares cannot.

Observation 1.3

the driving force comes from the apparent wind.No apparent wind, no thrust——so the presence of a cap is settled at this one point.

Question: why can a sailing craft outrun the wind?

2. One Falls to 0; the Other Rises to 50.9902

Computation 2.1: apparent wind at $V_t = 10$ m/s (computed in this paper).

Boat speed [m/s]	Across the wind [m/s]	Angle off the bow [deg]	Dead downwind [m/s]
0	10.0000	90.00	10.0000
5	11.1803	63.43	5.0000
10	14.1421	45.00	0.0000
20	22.3607	26.57	10.0000
30	31.6228	18.43	20.0000
50	50.9902	11.31	40.0000

Observation 2.2

this is the core of the paper.On the 10 m/s row the last column is 0.0000 and the second is 14.1421——same wind, same boat speed: the heading alone decides whether the thrust vanishes or the boat feels a wind 41 per cent stronger than the true one.

Observation 2.3

the across-the-wind column rises monotonically.From 10.0000 to 50.9902——faster means a stronger wind, and there is no ceiling.

Observation 2.4

the downwind column falls and then rises. $10 \rightarrow 5 \rightarrow 0 \rightarrow 10 \rightarrow 20 \rightarrow 40$ —it turns at $V_b = V_t$, but past that the wind blows from astern to ahead and pushes back.

Observation 2.5

the angle column closes down. From 90 degrees to 11.31—the faster you go the more the wind comes from ahead; the sail is sheeted in, but the wind itself does not weaken.

Observation 2.6

the apparent wind first exceeds five times the true wind at 49 m/s. 49.912 at 48.9 m/s, 50.010 at 49 m/s—the boundary is bracketed from both sides.

3. The Ceiling Is Set by Both Sail and Craft

Computation 3.1: maximum speed ratio from the drag angles (computed in this paper).

$$\frac{V_b}{V_t} \Big|_{\max} = \frac{1}{\frac{1}{(L/D)_{\text{sail}}} + \frac{1}{(L/D)_{\text{craft}}}}$$

Craft	L/D (sail, craft)	Maximum speed ratio
Ice boat	5, 40	4.4444
Ordinary sailing boat	5, 5	2.5000

Observation 3.2

the ceiling clears “faster than the wind” easily. Both 4.4444 and 2.5000 exceed one—beating the wind speed is not an exception but the ordinary consequence of the formula.

Observation 3.3

the formula is symmetric in sail and craft. (100, 5) and (5, 100) both give 4.7619——improving only the sail buys exactly as much as improving only the craft.

Observation 3.4

so an ice boat is not fast because of its sail. The sail's L/D is held at the same 5——the only change is the contact side, from 5 to 40, and that alone turns 2.5000 into 4.4444.

Observation 3.5

the shape is that of Paper 384. There the frequency term came from the receiving antenna——here the apparent wind comes from one's own speed. In both, a quantity thought to be outside comes from one's own side.

4. The Cap Is Made by the Heading, Not by the Wind

Observation 4.1

the downwind cap is a consequence of geometry. Run with the wind and the difference closes——no improvement to the sail removes it.

Observation 4.2

the absence of a cap across the wind is also geometry. Orthogonal components do not cancel——
 $\sqrt{V_t^2 + V_b^2} > V_b$ always holds.

Observation 4.3

the driving force acts obliquely to the apparent wind. The sail generates lift, part of which points along the course——so a wind from ahead can still drive the boat.

Observation 4.4

they are different-root by the criterion of Paper 300.The true wind is set by the weather; the apparent wind by the weather and one’s own speed together—one word, “wind”, names two things with different roots.

Observation 4.5

the apparent wind is self-referential.Go faster and the wind strengthens; a stronger wind lets you go faster still—only drag stops it, and that is what produces the number 4.4444.

5. Separator: Is the Heading Parallel to the True Wind

Observation 5.1

separator—does the boat’s course lie along the true wind, or at an angle to it.

Heading	Apparent wind	At $V_b = V_t$	Ceiling
Parallel to the true wind	$ V_t - V_b $	0.0000	capped at V_t
At an angle	$\sqrt{V_t^2 + V_b^2}$	14.1421	set by drag

Observation 5.2

the separator is not continuous; only the parallel case is singular.Any angle other than zero, however small, removes the cap—a single point is the exception.

Observation 5.3

which is why running dead downwind is slow.Even when the destination is downwind, one sails at an angle and zigzags—the longer path arrives sooner.

Observation 5.4

this separator can be tested. Race the same craft dead downwind against a zigzag course——on ice the difference is an order of magnitude.

Observation 5.5

to be honest——both 4.4444 and 2.5000 come from a model holding the lift-to-drag ratios constant. In practice they vary with speed——what does not move is that the apparent wind reaches zero only dead downwind, and never on any other heading.

Observation 5.6

one last thing——“you cannot outrun the wind” is correct for exactly one heading. On that heading it is exactly correct——fail to check the scope of a true statement and its very truth manufactures the error.

6. Roll Call and Closing

1. A difference downwind, a sum of squares across (Section 1): **only the heading differs.**
2. 0.0000 downwind at $V_b = 10$ (Computation 2.1): **the thrust vanishes.**
3. 14.1421 across the wind at the same speed (Computation 2.1): **41 per cent above the true wind.**
4. 50.9902 at 50 m/s (Computation 2.1): **faster is stronger.**
5. Five times the true wind from 49 m/s (Observation 2.6): **bracketed both sides.**
6. An ice boat's ceiling is 4.4444 (Computation 3.1): **well past one.**
7. The formula is symmetric (Observation 3.3): **the sail alone is not enough.**
8. An ice boat's speed comes from the contact side (Observation 3.4): **the sail is the same 5.**
9. Only the parallel case is singular (Observation 5.2): **any angle removes the cap.**
10. The longer path arrives sooner (Observation 5.3): **zigzag downwind.**

Closing: a sail is pushed by the wind, so a boat cannot outrun the wind——so it seems——yet changing only the heading removes that cap. Dead downwind the apparent wind is $|V_t - V_b|$; across the wind it is $\sqrt{V_t^2 + V_b^2}$ ——one is a difference and reaches exactly zero at $V_b = V_t$; the other is a sum of squares and never does. Since the driving force comes from the apparent wind, the presence of a cap is settled at this one point. On the 10 m/s row, downwind

gives **0.0000** m/s and across the wind **14.1421** m/s——same wind, same boat speed: the heading alone decides whether the thrust vanishes or the boat feels a wind 41 per cent stronger than the true one. The across-the-wind column rises monotonically from 10.0000 to **50.9902**, with no ceiling. The angle closes from 90 degrees to 11.31, but the wind itself does not weaken. Five times the true wind is first exceeded at 49 m/s, bracketed by 49.912 at 48.9 m/s and 50.010 at 49 m/s. The ceiling is set by both sail and craft—— $V_b/V_t|_{\max} = 1/(1/(L/D)_{\text{sail}} + 1/(L/D)_{\text{craft}})$, giving **4.4444** for an ice boat (5, 40) and **2.5000** for an ordinary boat (5, 5). Both exceed one, so beating the wind speed is not an exception but the ordinary consequence of the formula. The formula is symmetric: (100, 5) and (5, 100) both give 4.7619, so improving only the sail buys exactly as much as improving only the craft. An ice boat is therefore not fast because of its sail——the sail stays at $L/D = 5$, and changing only the contact side from 5 to 40 turns 2.5000 into 4.4444. The cap is made by the heading, not by the wind——running with the wind closes the difference, and no improvement to the sail removes it; orthogonal components do not cancel, and $\sqrt{V_t^2 + V_b^2} > V_b$ always holds. As in Paper 384, where the frequency term came from the receiving antenna, a quantity thought to be outside comes from one's own side. By the criterion of Paper 300 they are different-root: the true wind is set by the weather, the apparent wind by the weather and one's own speed together. One thing does the separating——does the boat's course lie along the true wind, or at an angle to it. The separator is not continuous: only the parallel case is singular, and any angle other than zero, however small, removes the cap. Which is why one sails at an angle and zigzags even when the destination is downwind——the longer path arrives sooner. Race the same craft both ways on ice and the difference is an order of magnitude. To be honest——both 4.4444 and 2.5000 come from a model holding the lift-to-drag ratios constant, and in practice they vary with speed. What does not move is that the apparent wind reaches zero only dead downwind, and never on any other heading. One last thing——“you cannot outrun the wind” is correct for exactly one heading. On that heading it is exactly correct. Fail to check the scope of a true statement and its very truth manufactures the error.

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