# SPEED, WIND AND FUEL

## Lessons from long-range flights

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Large fuel savings are available simply by slowing down. If we want the very most nautical air miles (NAM) per gallon, we need to fly at best range speed (Vbr). The indicated air speed (IAS) yielding the highest true air speed (TAS) divided by fuel flow is Vbr for that aircraft weight. Vbr for my Bonanza is about 115 KIAS at 3,400 pounds.

Vbr is independent of altitude, but does vary with the square root of aircraft weight. At Vbr, higher altitude yields higher TAS but also higher fuel flow, so there's no change in NAM/gallons. Range performance is independent of altitude.

NAM/gallon at Vbr is inversely proportional to aircraft weight. With tip tanks and a 105-gallon ferry tank (on a ferry permit), our Bonanza can carry 1,350 pounds of fuel, so a max-range flight involves serial power reductions to hold decreasing Vbr as weight decreases and NAM/gallon increase. This is an indirect method of maintaining a constant angle of attack that approximates L/D max.

| Weight | Vbr KCAS | 105% Vbr | KTAS @ 10,000' (STP) |
|---|---|---|---|
| 3800 | 122 | 128 | 148 |
| 3400 | 115 | 121 | 140 |
| 2900 | 106 | 111 | 129 |
| 2400 | 97 | 101 | 117 |

Using 105% of Vbr still yields 99% of max range, and seems worthwhile. Higher percentages over Vbr are nicer if fuel allows. For a long oceanic leg, I like alternate fuel plus three hours.

Flying at these low airspeeds will usually require less than 60% power, where leaning to peak EGT can't hurt the engine and will save fuel. Higher MP and lower rpm can reduce friction losses and improve propeller efficiency. Going lean-of-peak EGT improves range and is kinder to engines that are set up for this, with lower combustion pressures and cylinder head temperatures. When operating LOP, power is proportional to fuel flow.

### Wind

Putting airspeed and power management together gets best range performance in still air, but there is always wind, which needs its own strategy, beyond picking best altitude.

Tailwinds are great—you can just get there sooner, or you can throttle back to let your ground speed equal your usual TAS, or less, with resultant fuel savings. Or with the fuel saved, higher power settings can be used to lower your trip time even more.

Pilots sometimes theorize they should speed up in a headwind for better range performance. That is only true if already flying at Vbr, in which case adding just a third to a quarter of the headwind component to Vbr works OK as a rule of thumb.

Flying at normal cruise speeds, when headwind starts eating into reserves, range will more likely improve by slowing down. In this situation the headwind can have a doubled negative effect on groundspeed, as in Figure 1.

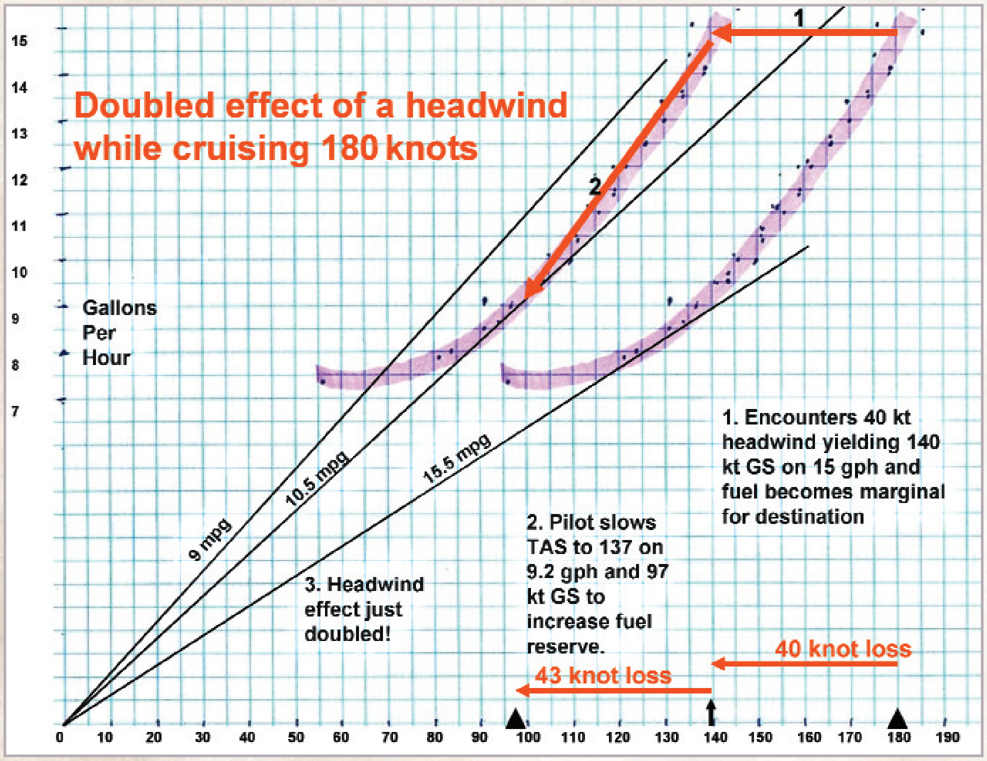
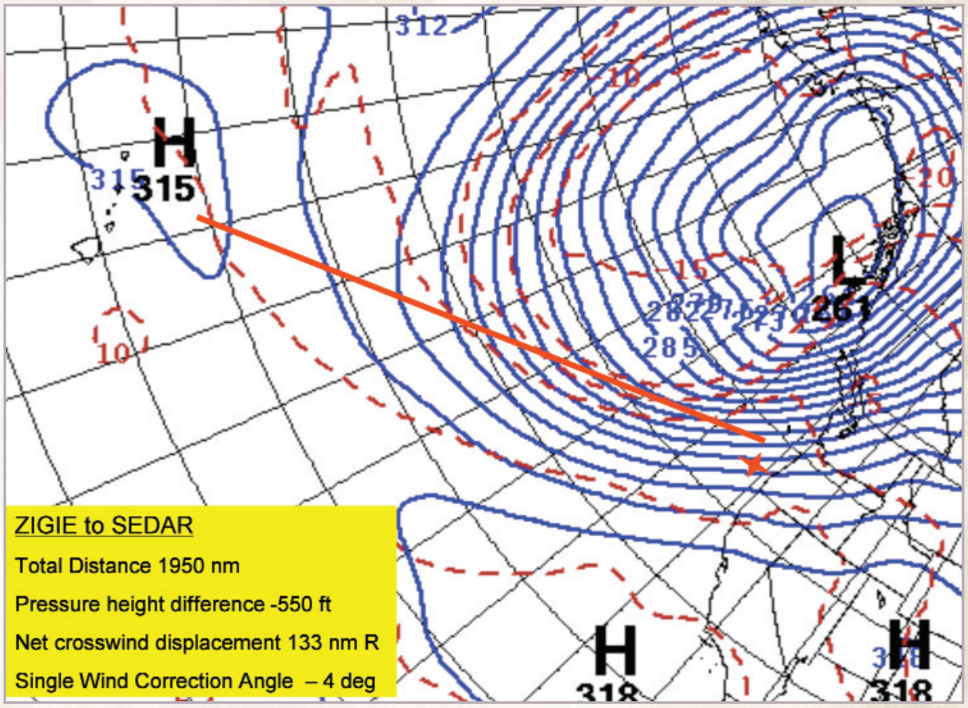


Figure 1: Cruising 180 KTAS, headwind causes 40-knot decrease in ground speed. Pilot decreases speed for best ground miles per gallon, losing another 43 knots. *Moral: Take off with more fuel when you anticipate a headwind, or plan an intermediate stop.*

### Crosswinds and pressure patterns

Consider that whenever an aircraft is crabbed into a crosswind, ground speed is reduced. We all learned that the shortest distance between two points is a straight line (great circle track); however, that straight line does not necessarily represent the shortest flight time.

Figure 2 is a 700-millibar pressure pattern chart valid for a Bonanza flight in 2006 from Honolulu to Bellingham, Washington, via oceanic waypoints ZIGIE and SEDAR. A glance at the chart gives the expectation of a nice tailwind, initially quartering from the left and later from the right. Flight planning to maintain the great circle track by predicted zone winds gave a wind correction angle of -11 degrees, changing to +15 degrees by and beyond SEDAR.



ZIGIE to SEDAR

Total Distance 1950 nm

Pressure height difference -550 ft

Net crosswind displacement 133 nm R

Single Wind Correction Angle – 4 deg

Figure 2: RED LINE is great circle route flown. RED STAR is net crosswind displacement by wind if no crab used. The "315H" north of Hawaii means 700 mB pressure height is 3,150 meters/10,350'. There is a 30 meter/99' height difference between contours, so height at SEDAR (eastern end of red line) is 2,970 meters/9,800'.

GPS altitude 10,620

Pressure altitude 11,000

D = 380 ft/ 116 meters

Figure 3: Approaching SEDAR on flight from Honolulu. Note difference D between pressure altitude and GPS altitude, consistent with 700 mB pressure chart. GPS altitude is analogous to radar altitude over the sea. Altimeter set at 29.92" displays pressure altitude.

700 millibars is the barometric pressure at 9,879' in a standard atmosphere (altimeter 29.92). But the high pressure northwest of Hawaii is marked 315, meaning 700 mb is at 3,150 meters/10,350', which would be your true altitude there if your altimeter (set 29.92) read 9,879'. Flight away from the high while maintaining a constant pressure altitude would entail a descent of 30 meters/99' across each of the contour lines. This change could be noted by radar altimetry over the sea, giving inflight pressure data to flight navigators.

Understanding that Coriolis force causes airflow around pressure centers along contour lines, related to latitude, John Bellamy of the University of Chicago derived formulas in the 1940s that solved drift using pressure gradients and latitude. This allowed flight navigators using pressure data to plan a single wind correction angle as well as to find lateral drift in flight.

The Jeppesen CR3 circular computer takes the difference of pressure levels, TAS and mid latitude (35 deg), then solves the flight's net crosswind displacement as 133 nm right. The back side of the CR3 takes distance between points (1,950 nm), airspeed (150 kts), lateral displacement (133 nm) and solves to eliminate that lateral displacement with a minus 4 degrees (left) wind correction angle for the entire flight.

Crossing each isobar line, from whatever angle, here causes a lateral displacement of 23 miles. The angle at which the flight crosses the contours does not matter—by geometry the lateral displacement is the same.

That single 4-degree left wind correction angle would allow this flight to drift left of, then right of, then back onto the great circle route upon reaching SEDAR, so the track would have been a big S in the sky, noncompliant with the published oceanic route, minimally compatible with GPS, perhaps unacceptable to ATC, but with less flight time and fuel consumption by eliminating unneeded crab.

The airlines now prefer lightweight flight attendants, winglets, less water, food and even fuel onboard, all to save fuel. What about pressure pattern navigation to minimize fuel burns? Computer modeling now gives accurate pressure forecasting. Derivation of single wind correction angle and +/- wind component for a flight is not a huge challenge for a computer. Software revisions might allow GPS navigation on the curved path needed for that minimum flight time. Advances in air traffic control management might avoid traffic conflicts on such random or curved routes.

More realistically, and for now, understanding pressure patterns can help us choose more fuel-efficient airway routes and VFR routing. Keeping lows to the left, highs to the right can sometimes be managed by route choice or timing. Domestic airline flights tend to have several routes stored, picking that which gives the best flight time for current conditions. We can do the same thing with DUAT flight planner, which seems quite accurate.

## Critical fuel

The same concepts apply for a critical fuel situation. Suppose you unexpectedly have a missed approach and marginal or uncertain fuel to get to an alternate. It's time to slow down to Vbr, decrease rpm, lean the mixture and head for a downwind alternate. The legal requirement for alternate fuel plus 45 minutes at normal cruising speed does not mean you can't reduce speed in a pinch to improve your fuel margin.

Lacking confidence of fuel remaining might prompt bad decisions leading to a disaster, so we should always feel secure about fuel on board. Fuel totalizers are great, they do need to be checked against fill-ups at the pump, and levels must be visually confirmed. Running a tank dry sounds risky, but there is benefit to learning how much fuel can be consumed from a tank in level flight.

For instance, the main tanks in our Bonanza are 40 gallons, 37 useable. But by running tanks dry (with one hand on the fuel selector), I've learned that either of our mains will take slightly over 41 gallons after running dry in level flight. *Your tanks may differ.* Switching to the left tank after burning 41 gallons rather than 37 from the right tank, four gallons of unusable fuel have been reclaimed—enough for 30 minutes of flight at Vbr/minimal weight. I don't often do this, but do not hesitate if fuel is tight.

Cruise control for every flight involves knowledge of wind and balance of flight time against fuel consumption, while setting aside alternate and reserve fuel appropriate for the route flown. It's best to know your fuel quantity and how to use it most efficiently.

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