

Main goal

Although we sail and trim our boat to the apparent wind speed (AWS) and angle (AWA), as this is what the boat is actually seeing, the boat’s performance is measured at a given true wind speed and angle. This is because the true wind data stays constant irrespective of where the boat is pointing (Not effected by apparent wind). Effectively it’s a constant reference point.

Most commonly the true wind speed will read higher downwind than upwind - or the true wind direction will be different on starboard tack to port - without there being any change in the real (ground) Wind. The reason for true wind being wrong is error in the apparent wind. True Wind can be calculated from apparent Wind data and corrections can then be applied.

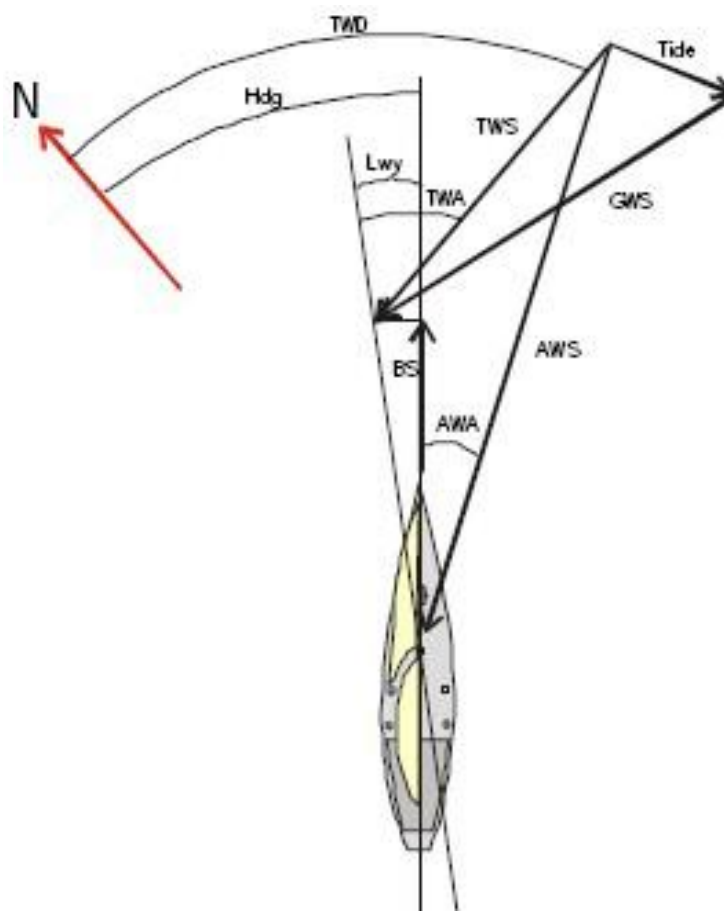


Figure 1: Wind triangle

Input: Instrument reading → **Output:** Actuals: TWA, TWS, VMG, VMC, GWS, Tide-speed and -direction

Sources used: <http://www.compusail.co.za/html/Instruments.pdf>
<http://www.altendorff.co.uk/archives/1116>
<http://www.orc.org/rules/Speed%20Guide%20Explanation%202010.pdf>

Definitions

- AWS is the wind velocity that is measured directly across the deck of the boat—right into your face.
- AWA is the wind angle that is blowing across the deck of the boat relative to the boat’s center-line.
- The tide wind which is produced by the motion of the water (Hdg, STW) relative to the land (COG, SOG).

An overview of possible wind data corrections will be described.

IV.1 Correction for Wind gradient

TWS given on a polar diagrams are based at 10 meters (33 ft.) above the water. To correct the wind sensor for height a rough approximation can be used ("Input by screen Calibration parameters"):

$$\begin{aligned} \text{Meas Wind Speed 33ft} &= \text{Meas Wind Speed} * [1 / (0,9 + 0,003 * H \text{ wind sensor in ft})] \\ \text{TWS 10mtr} &= \text{TWS wind sensor} * [1 / (0,9 + 0,01 * H \text{ wind sensor in mtr})] \end{aligned} \quad \text{OR}$$

IV.2 Correction for Heel

Measured Wind Angles can change as much as 4° when heel changes from 10° to 24°. This angle will continue to narrow as heel angle increases until the Measured Wind Angle equals 0 at 90° heel. The NMEA sentence XDR could be used regarding Heel.

$$\text{Corrected Meas WA} = \tan (\sin (\text{Meas WA}) * \cos (\text{Heel})) / \cos (\text{Meas WA})$$

IV.3 Correction for Wind Sheer

Wind Sheer is the change in wind direction with altitude. This can be detected by your instruments reading different wind angles from tack to tack. However Heel must be measured.

IV.4 Correction for Mast Twist

The tip of the mast will twist because of the loads imposed by the sails. Although you may think the masthead unit is lined up with the centreline because the apparent wind angle is the same on both tacks, in fact it is pulled off a few degrees both sides by the mast tip twisting when you are sailing.

IV.5 Correction for Upwash and Leeway

Leeway angle and Upwash from the sails must be applied simultaneously. In smooth water to windward at wind velocity of 10 knots, the opposing corrections almost cancel out for most boats.

Upwash is at a maximum going to windward in light to moderate air and drops to zero in a run condition. The controlling influence is the lift coefficient of the sail plan. For sailing windward lift is maximized, but lift drops off to zero when running and the drag then provides the driving force. For a rough correction of wind direction instrument reading, multiply the lift coefficient by 4 and subtract from the reading.

$$\text{The Leeway angle: } Lwy = (K * \text{Heel}) / BS^2.$$

Where K is based at Designers information and values around 1 for an AC boat and 10-15 for a typical modern race boat. A small investigation did not result in K-values. To simplify a table can be used:

Leeway Angles (in degrees)	-----WIND STRENGTH & POINTS OF SAIL-----							
	3-10 knots		11-21 knots		22-33 knots		34-65 knots	
BOAT TYPE	beat	reach	beat	reach	beat	reach	beat	reach
Shallow-keel cruising sailboat	10	5	8	4	12	10	20	12
Deep-keel racer	6	4	4	2	6	4	12	6
Large cruising sailboat under power	4	2	6	4	10	8	20	12
Large cruising sailboat under sail	10	4	8	4	12	12	20	15
User defined ???

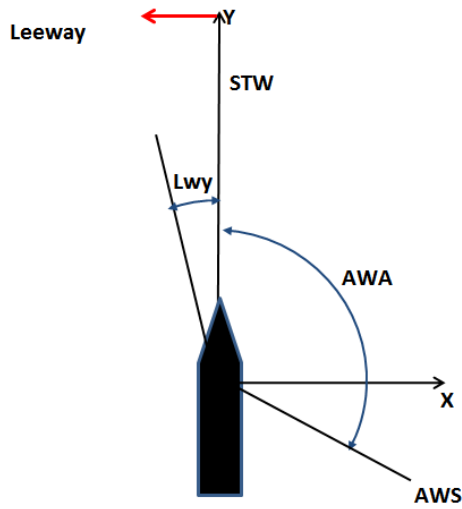
Table I: Leeway Angles (Lwy)

Source: <http://www.irbs.com/lists/navigation/9907/0052.html>

Measuring Heel is the key. Most OpenCPN users, being not part of the racing community, don't measure Heel therefor only Wind gradient and Leeway will be explained for now.

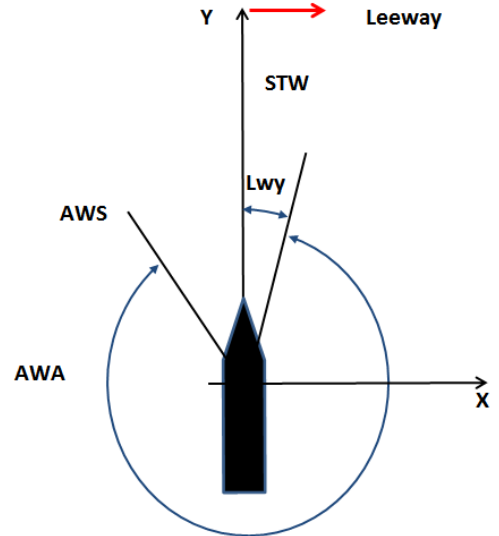
VI.6 **Vector Leeway**

Wind from Starboard side ($0^\circ < AWA < 180^\circ - Lwy$)



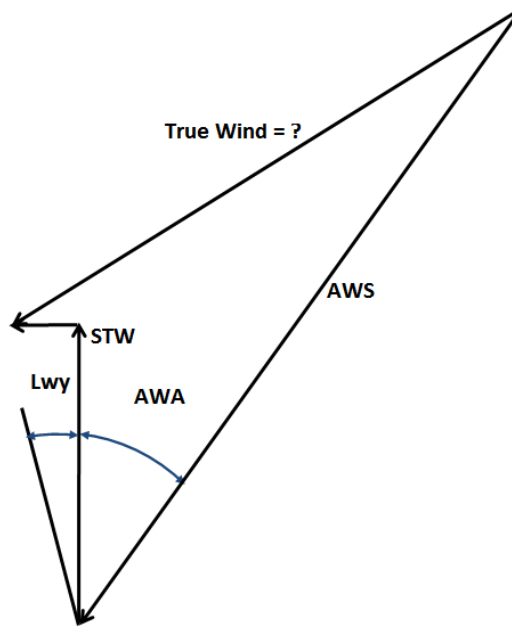
$$X = - \tan (Lwy) * STW$$

Wind from Port side ($180^\circ + Lwy < AWA < 360^\circ$)



$$X = + \tan (Lwy) * STW$$

IV.7 **Vector True Wind**



$$\text{TWS wind sensor} = [(\text{AWS} * \sin (\text{AWA}) \pm \tan (\text{Lwy}) * \text{STW})^2 + (\text{AWS} * \cos (\text{AWA}) - \text{STW})^2]^{1/2}$$

$$\text{Actual TWS} = \text{TWS wind sensor} * [1 / (0,9 + 0,01 * \text{H wind sensor in mtr.})]$$

$$\text{Actual TWA} = \tan [(\text{AWS} * \sin (\text{AWA}) \pm \tan (\text{Lwy}) * \text{STW}) / (\text{AWS} * \cos (\text{AWA}) - \text{STW})]$$

Add 180 degrees to Actual TWA if it is negative.

IV.8 **VMG**

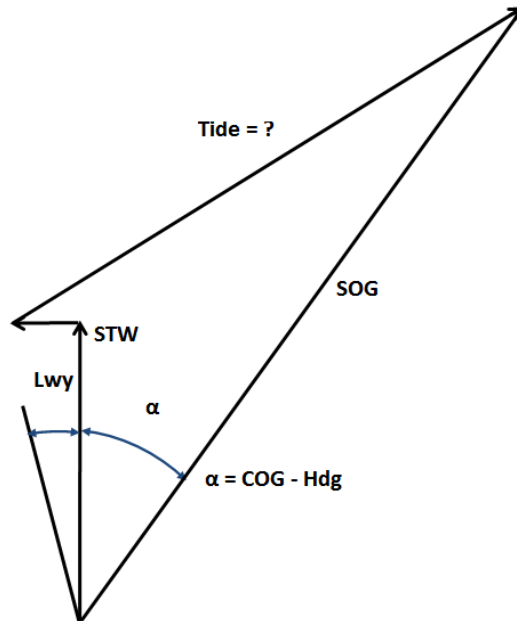
$$\text{Actual VMG} = \cos (\text{Actual TWA}) * \text{STW}$$

IV.9 **VMC**

$$\text{Actual VMC} = \cos (y) * \text{STW} \quad y = \text{corner between Bearing} - \text{Heading.}$$

IV.10 **Vector Tide**

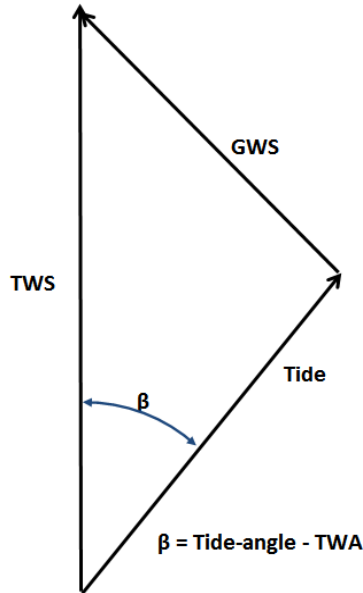
Convert COG to Magnetic North, see <http://opencpn.org/magnetic-declination>



Actual Tide-speed = $[(SOG * Sin (\alpha) \pm Tan (Lwy) * STW)^2 + (SOG * Cos (\alpha) - STW)^2]^{1/2}$

Actual Tide-angle = $Tan [(SOG * Sin (\alpha) \pm Tan (Lwy) * STW) / (SOG * Cos (\alpha) - STW)] + Hdg$

IV.11 **Vector Ground Wind**



Actual GWS = $[(Actual\ Tide\ -\ speed * Sin (\beta))^2 + (Actual\ Tide\ -\ speed * Cos (\beta) - TWS)^2]^{1/2}$

Actual GWA = $Tan [(Actual\ Tide\ -\ speed * Sin (\beta) / (Actual\ Tide\ -\ speed * Cos (\beta) - TWS)] + TWA - Lwy + Hdg$

Convert actuals (GWS, GWA, Tide-speed and Tide-angle) to True North for comparison with forecasts.

IV.12 **Actual Tack / Gybe (the last one)**

Not worked out yet, see also Attachment VI Log.