Attachment III: Calculating True Wind, Tide, Ground Wind (Speeds and Directions) and VMG.

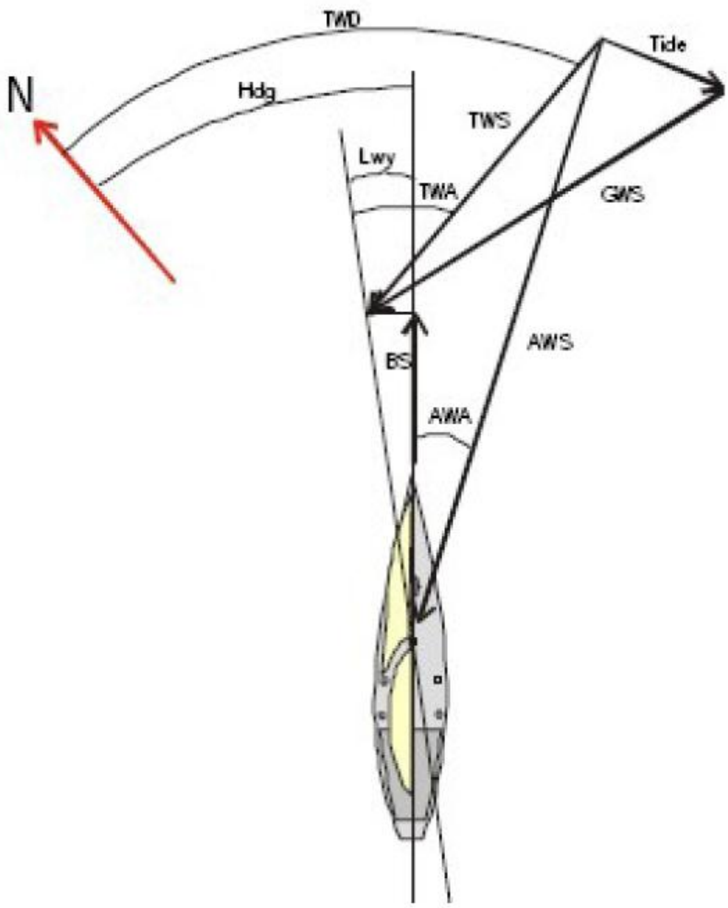
Main goal

To develop a calculation based at data coming form (basic) navigational instruments for Ground Wind Speed (GWS) and Ground Wind Angle (GWA) because these are essential for polar calculations. This development starts with the basics. Corrections for K (boatdesigner's info), Heel, Wind Sheer and Wind gradient are not included (jet).

Navigational Instruments

-	GPS	Course over Ground (COG), Speed over Ground (SOG), Position (POS)
-	COMPASS	Magnetic Heading (Hdg)
-	LOG	Speed Trough Water (STW)
-	Wind sensor	Apparent Wind speed (AWS) , Apparent Wind Angle (AWA)

Wind triangle



Source: http://www.compusail.co.za/html/Instruments.pdf

Definitions

- AWS is the wind velocity that is measured directly across the deck of the boat—it is the wind you feel on your face.
- AWA is the angle of the wind that is blowing across the deck of the boat relative to the boat's center-line. The direction of the (vector) force of AWA = AWA + 180.
- Leeway is the drift of a ship leeward of the course being steered.
  Leeway calculations are based at: Leeway = (K * Heel) / BS2. Where K is based at Designers information and Heel (H) should be measured separately. To simplify this a table is used, see Table I: Leeway Angles.

Calculations

3.2.1 **Vector BS** **is determined by GPS (SOG) and Compass (Hdg)** **????**

SOG consist of STW + Tide-speed because both cause AWS.
Hdg reflects the point of sail and this is the bases for AWA.

Vector BS : $X_{BS} = \text{Cos}\,(90° - \text{Hdg}) \;*\; \text{SOG}$
: $Y_{BS} = \text{Sin}\,(90° - \text{Hdg}) \;*\; \text{SOG}$

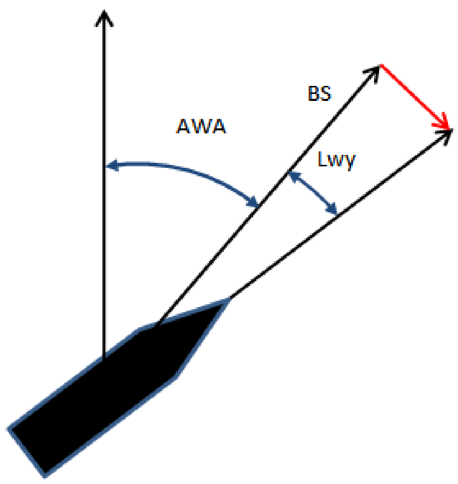
3.2.2 **Vector Leeway**

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
Dedicated parameters	…	…	…	…	…	…	…	…

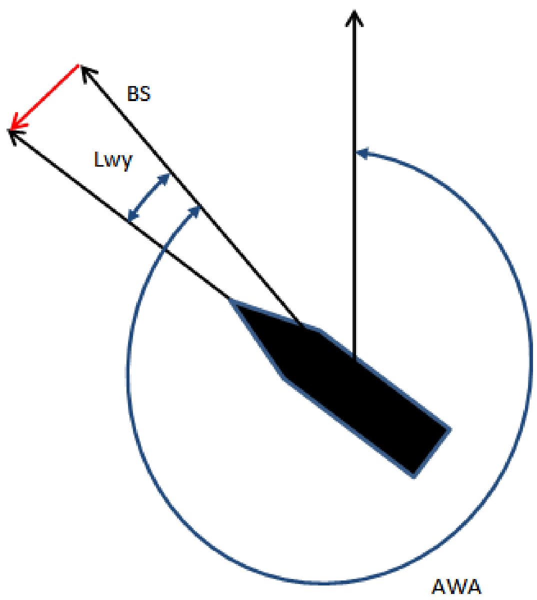
Table I: Leeway Angles Source: http://www.irbs.com/lists/navigation/9907/0052.html

Two situations of Leeway are distinguished:

Wind over Starboard side (0˚ > AWA > 180˚)



Wind over Port side (180˚ > AWA > 360˚)



Vector Lwy : Starboard : Lwy = AWA + 90° ($0° + \text{Lwy} < \text{AWA} < 180° - \text{Lwy}$)
: Port : Lwy = AWA – 90° ($180° + \text{Lwy} < \text{AWA} < 360° - \text{Lwy}$)

: $X_{Lwy} = \text{Cos}\,(90° - \text{AWA} + \text{Lwy}) \;*\; \text{Tan}\,(\text{Lwy}) \;*\; \text{SOG}$
: $Y_{Lwy} = \text{Sin}\,(90° - \text{AWA} + \text{Lwy}) \;*\; \text{Tan}\,(\text{Lwy}) \;*\; \text{SOG}$

3.2.4 **Vector AWS**

Vector AWS : $X_{AWS} = \text{Cos}\,(90° - \text{Hdg} + \text{AWA} + 180°) \;*\; \text{AWS}$
: $Y_{AWS} = \text{Sin}\,(90° - \text{Hdg} + \text{AWA} + 180°) \;*\; \text{AWS}$

(+ 180 because the force is opposite of the wind direction)

3.2.5 **Vector TWS = vector AWS + vector BS + Vector Lwy**

TWS $= ((X_{AWS} + X_{BS} + X_{Lwy})^2 + (Y_{AWS} + Y_{BS} + Y_{Lwy})^2)^{½}$

TWA $= Tan ((Y_{AWS} + Y_{BS} + Y_{Lwy}) / (X_{AWS} + X_{BS} + X_{Lwy}))$

TWA + 180 because the force is opposite of the wind direction **?????**

Convert TWA magnetic to TWA True see attachment V: Conversion.

3.2.6 **Vector Tide = vector GPS (COG, SOG) - vector LOG (Hdg, STW)**

Vector GPS : X_{GPS} = Cos (90° - COG) * SOG
: Y_{GPS} = Sin (90° - COG) * SOG

Convert HDG magnetic to HDG True see attachment V: Conversion.

Vector LOG : X_{LOG} = - Cos (90° - Hdg) * STW
: Y_{LOG} = - Cos (90° - Hdg) * STW

Tide-speed $= ((X_{GPS} + X_{LOG})^2 + (Y_{GPS} + Y_{LOG})^2)^{½}$

Tide-angle $= Tan ((Y_{GPS} + Y_{LOG}) / (X_{GPS} + X_{LOG}))$

For non-tidal waters (Tide = 0) GWS = True wind Speed and GWA = True wind Angle.
This could lead to back calculate Leeway. Based at the experiences reported in the article of "Compusail performance sailing services" this does not seem to be an option.

3.2.7 **Vector GWS = vector TWS – vector Tide**

Vector TWS : X_{TWS} = Cos (90° - $TWA_{True\ North}$) * TWS
: Y_{TWS} = Sin (90° - $TWA_{True\ North}$) * TWS

Vector Tide : X_{Tide} = Cos (90° - $\text{Tide-angle}_{True\ North}$) * Tide-speed
: Y_{Tide} = Cos (90° - $\text{Tide-angle}_{True\ North}$) * Tide-speed

GWS-speed $= ((X_{TWS} + X_{Tide})^2 + (Y_{TWS} + Y_{Tide})^2)^{½}$

GWS-angle $= Tan ((Y_{TWS} + Y_{Tide}) / (X_{TWS} + X_{Tide}))$

If TWA and Tide-angle are base at True North then GWS-angle is also based at True North

3.2.8 **VMG**

VMG = cos(TWA) x BS

Boat speed is determined by:
- S.O.G Boat performance including tidal effects and Leeway.
- STW Boat performance only.