Anemotracker
Detailed documentation

Calypso Instruments

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IMPORTANT NOTE. This documentation was last updated for Version Revision 11-06-2024. If your current app version is newer than this date, there might be features still not detailed in this document. You can find the app version at the top of the Drawer Panel. The VR is given in the format dd-mm-yyyy.

This manual is intended for users interested in the technical aspects of the app and how the true wind is inferred from the apparent wind and the GPS data. If you are looking for an user friendly 'Starting Guide', you should check the User Manual, available in our website, under Technical Information (as this one).

1 App Structure

The app is composed of three main components that the user can interact with, and that can be visually identified on figure 1, are:

1. **Drawer Panel**. The drawer panel allows the user to access general important information, as it can be the wind meter battery level or the list of connected devices. Additionally, it allows the user to access different main sections of the app, like Sailing, Ballistics or the Live Tracking screen.

2. **Bottom Navigation Bar**. The navigation bar allows the user to access the different subsections within one of the main sections of the app. For instance, changing between the different screens on the Sailing section (accessible from the drawer panel).

3. **Current Page**. This is the current page, that is accessed through the Drawer Panel and Navigation Bar menus. Its appearance can vary widely from a map view, variable plots or several displays with the numeric values of wind data.

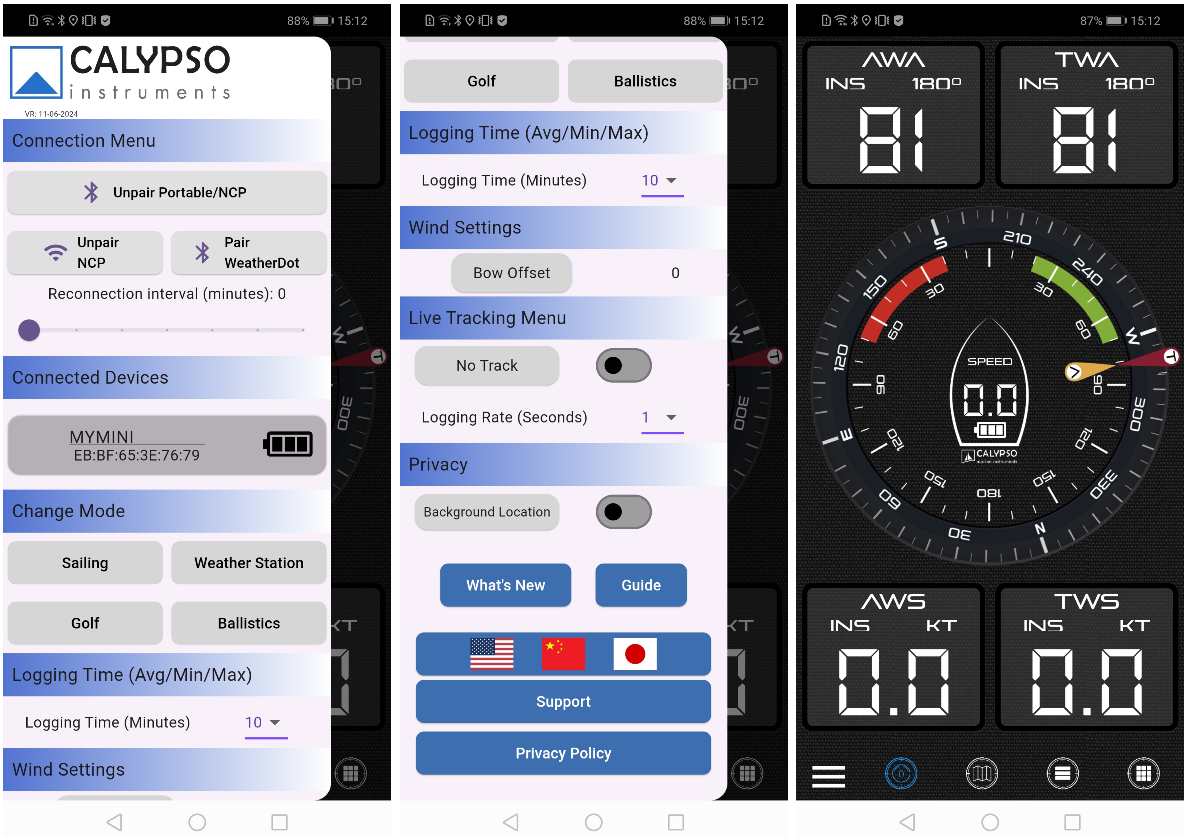

Figure 1: The 3 main components of Anemotracker's structure. The two images on the left show the Drawer Panel. The image on the right shows the Bottom Navigation Bar and the current page.

Besides from those interactive components, the app is organised in different main sections, that give access to several pages or subsections. The main four sections are Sailing, Weather Station, Golf and Ballistics. Here is an overall view of the section/subsection tree:

1. **Connection Screen**. Accessed with "Pair Portable/NCP" or "Pair WeatherDot" buttons. It shows an screen with all available compatible Bluetooth devices, that can be filtered by MAC address or device name (the name can be modified when connected).

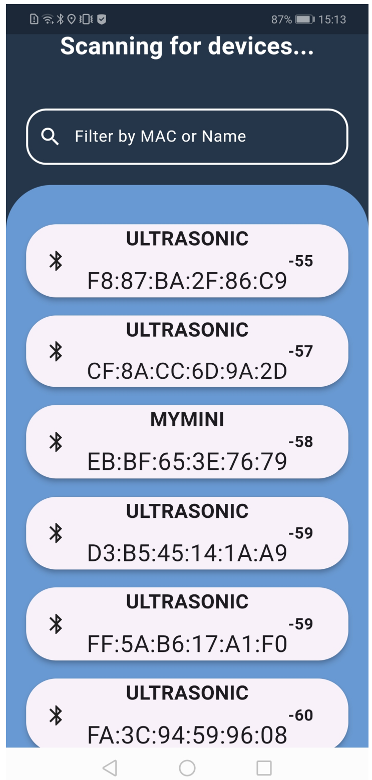

Figure 2: Connection screen showing several Portable Solar/Mini wind meters with default name, plus one with a custom name 'MYMINI'. As we can see, they are arranged in decreasing order of RSSI (the negative number on the right). What this means, is that the upper on the list, the better the signal received from that particular device.

2. **Sailing**

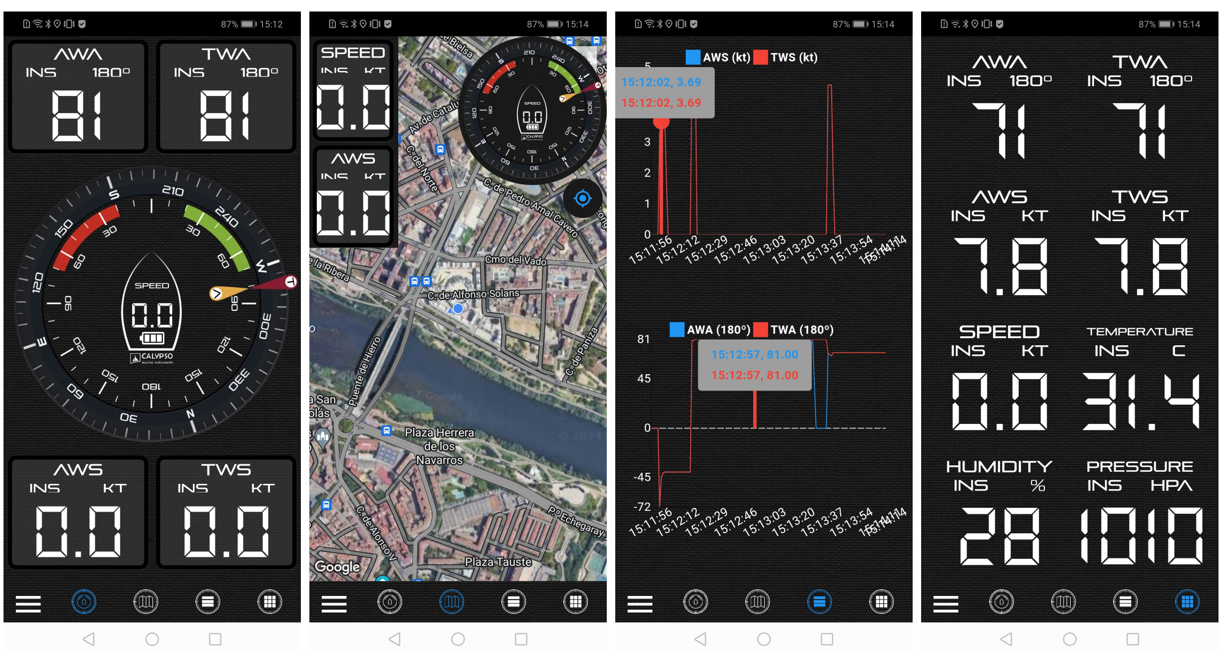

Figure 3: The four different pages withing sailing mode; from left to right: Main page, Map page, Plots page and Data page.

3. **Weather Station**

Figure 4: Analogously to Sailing mode, we find four screens on Weather Station mode. The Map page is replaced with an additional Plot page, and other variables gain importance in this mode. Temperature, Humidity and Pressure will take a more important role, compared to Sailing mode. There is a fourth page, almost identical to the Sailing data page, so not of much interest to display here.

4. **Golf**

Figure 5: Golf mode features just a simple screen with a clear view of the direction and the speed of the wind.

5. **Ballistics**

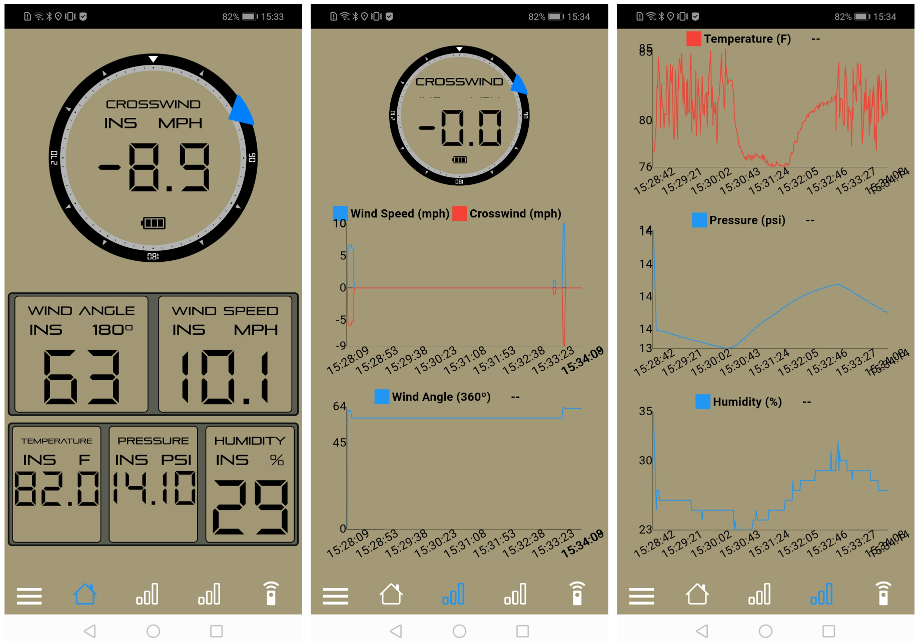

Figure 6: In Ballistics, as in Weather Station, Humidity Pressure and Temperature become important variables in the computation of a ballistic trajectories. The three first pages are somehow similar to Weather Station, and there is a fourth page that is reserved for some Ballistic specific products: Applied Ballistics Mini and the ULP with LoRa wind data transmission.

6. **Live Tracking Screen**

(a) Track list page

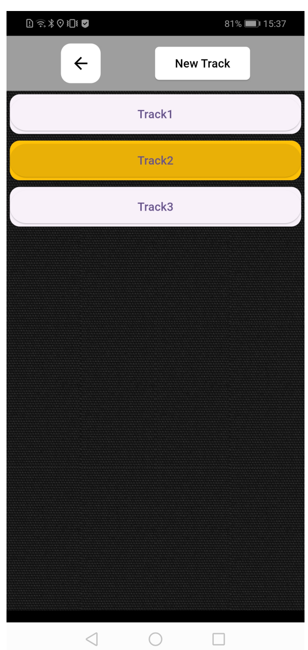

Figure 7: The Live Tracking Screen shows a list of all past recorded tracks. The current active track will be highlighted in yellow. From this screen you can either create a new track, continue/edit an already existing one, or export any of the available tracks logged data for a further in depth analysis.

All of the above sections can be accessed from the Drawer Panel, while the subsections are navigated with the bottom navigation bar.

2 List of Technical Terms and Data Display Configuration

Since Data Displays can display all possible variables with their different possible modes, ahead a detailed definition of all display and variable related terms will be presented. The configuration process is easy and can be pictured in the figure 2.

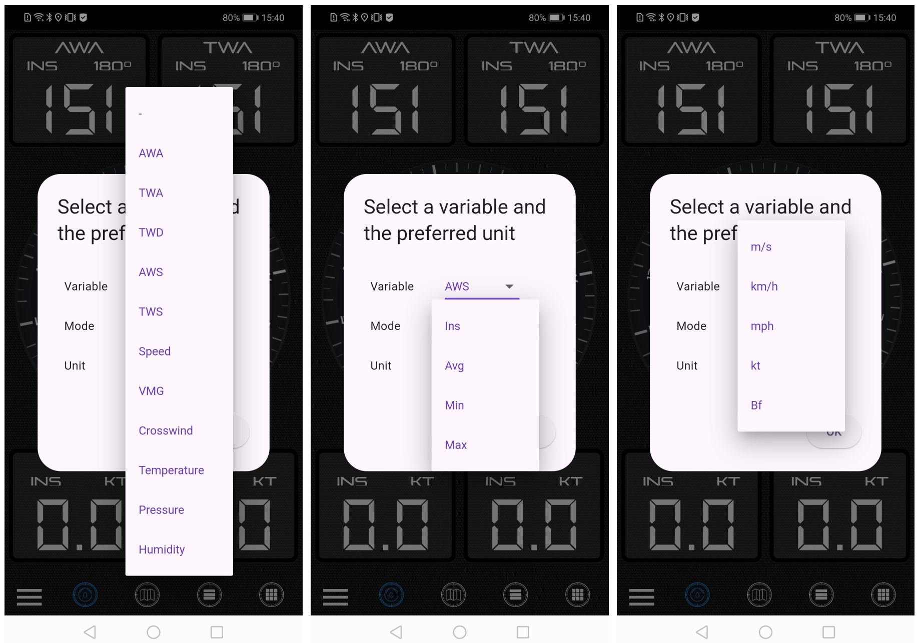

Figure 8: Pop up configuration window when holding any of the data displays throughout the app. Here we can see the different drop-down menus. The variable to display, the mode, and the units for that variable (the available units will change with the variable type: speed, temperature...). An in depth description of all the options is provided in this text.

Throughout all the app there are several displays that show (at most) 4 different things: current variable, mode, unit and numerical value. Although the displays differ in their look, they share exactly the same functionalities, even the ones inside the wind dial. Therefore, these four main elements deserve a detailed description:

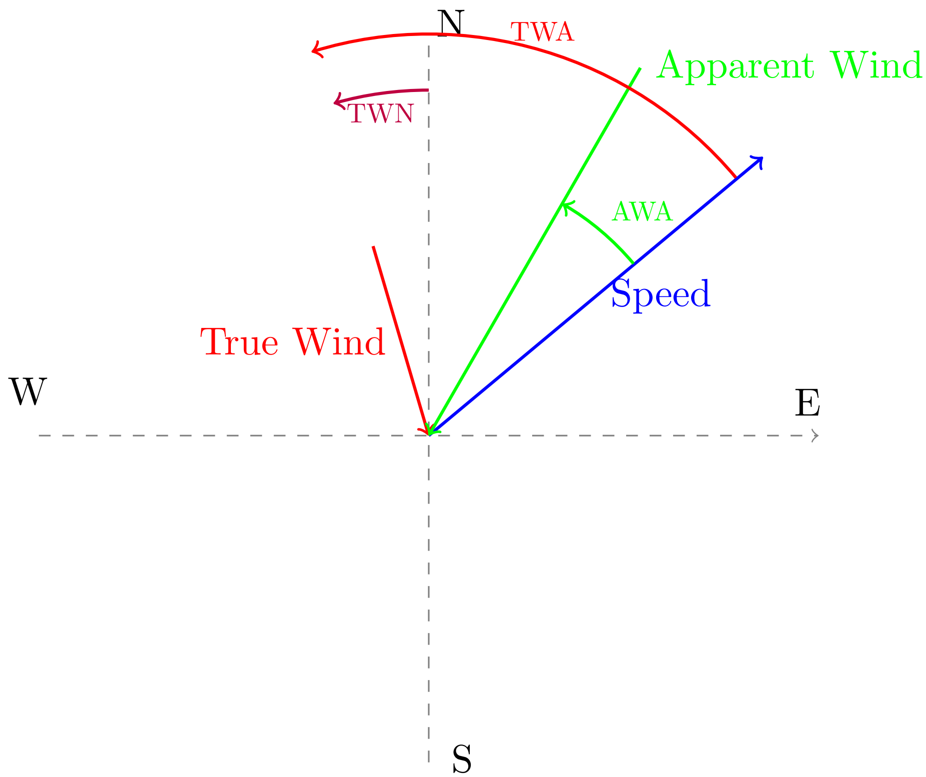

Figure 9: Simple drawing representing the True Wind vs the Apparent Wind. Note that, since the observer is moving as the blue arrow shows, it will feel a wind component equal to the blue arrow but reversed. The true wind represents the wind you would feel if Speed was zero. Therefore, the Apparent Wind arrow (green) is the sum of the red arrow plus the reversed blue arrow, and it is the wind that the observer feels in reality. About the angles, as you can see, AWA and TWA are measured from the direction of the movement, that we assume is aligned with the "north" mark of the wind meter. Here is also much easier to understand that TWN represents the same as the TWA but measured from the magnetic north, instead of the "north" mark of the anemometer.

- **Variable**. This is the variable to which all the other elements of the display refer, and it represents the type of data being shown. Below you can find a list of the different variables that you can see in the app. As an important side note, we should mention that the app puts apart wind variables into two main types: *apparent* wind and *true* wind. This term comes from the fact that the user can be standing still or moving (and it is widely use in sailing). For example, if the user is moving alongside with the anemometer, it will register an "apparent" wind speed and angle, that is not the same as if they were standing still. A, perhaps, quite familiar situation of this phenomenon is when you are riding a bike or running, and you feel an "apparent" wind, that is not the "true" wind *per se*.
  - **AWA**. The Apparent Wind Angle is the angle from which the wind meter is registering incoming wind. This angle is measured taking the "north" mark of the wind meter as 0º.
  - **AWS**. The Apparent Wind Speed is the wind speed the wind meter is measuring. As well as the AWA and TWA, this is affected by the movement of the wind meter.
  - **TWA**. The True Wind Angle is the angle from which the wind meter would be measuring wind *if it were still*. This angle is measured taking the "north" mark of the wind meter as 0º. Of course, if the wind meter is standing still, this value precisely matches AWA.
  - **TWS**. The True Wind Speed is the speed the wind meter would be reading *if it were still*. Of course, if the wind meter is standing still, this value is equal to AWS.
  - **TWD**. The True Wind Direction is the same thing as the TWA, but the angle is measured taking 0º at Earth's magnetic north (not the "north" mark of the wind meter). So it is the same angle as TWA but shifted to make 0º match the magnetic north. This is useful when one is interested in the

wind direction relative to the magnetic north, since it is important to be able to tell the wind from a universal reference and not referent to a ship that is moving or any other non-fixed reference point.

  – **CWS**. The Crosswind Speed is the speed of the wind perpendicular to the line of sight of the wind meter. This means that, if the wind meter has the "north" mark facing the front, the CWS will take into account just the wind speed component on the transversal (left to right) direction. This is of great importance in ballistics, because it quantifies (among other factors) how much your bullet will be deviated from its ideal straight trajectory. If the wind is blowing to the left, it will be negative and if it blows to the right, it will be positive. On the circular dials, the arrow on the right half will match a negative CWS, and the arrow on the left half will match a positive value; since the arrow tells where the wind comes from.
  – **Speed**. This shows the speed registered by the phone's GPS. In sailing, where you move alongside with the wind meter and looking to the same direction as the wind meter, it is used to compute TWA, TWS and TWN. The speed will be truncated to zero if it is lower than a threshold ($v_{\text{threshold}} = 1$ m/s), so non-real movements induced by the low accuracy of phone GPS does not give non-real True Wind values when standing still.
  – **VMG**. The Velocity Made Good is used typically in sailing. It shows the component of the speed that goes in the direction of the wind, so it reflects how much you are advancing against the wind when sailing at an arbitrary heading.
  – **Temperature**. This shows the current temperature in the area, provided by OpenWeather's API. If you have a WeatherDot connected, it will use its value instead.
  – **Pressure**. This shows the current pressure in the area, provided by OpenWeather's API. If you have a WeatherDot connected, it will use its value instead.
  – **Humidity**. This shows the current humidity in the area, provided by OpenWeather's API. If you have a WeatherDot connected, it will use its value instead.

- **Mode**. The mode represent the way in which the numerical value of the current variable is shown. Currently, there are 4 modes:
  – **Ins**. Instantaneous value of the variable. This is the most recent value measured of the selected variable.
  – **Avg**. Average value. This is the average value of the variable in the selected logging time interval. This is controlled by the Logging Time variable on the drawer menu.
  – **Min**. Minimum value. This is the minimum value of the variable in the selected logging time interval. This is controlled by the Logging Time variable on the drawer menu.
  – **Max**. Maximum value. This is the maximum value of the variable in the selected logging time interval. This is controlled by the Logging Time variable on the drawer menu.
- **Unit**. The unit will display the available units for each variable. If you miss some units for any variable type, feel free to contact us to implement it.
- **Numerical Value**. As you might guess, this is just the value of the selected variable with the selected configuration. The size of the displayed value should rescale to match the available display size.

As mentioned in the **Mode** section, on the drawer panel you will find a setting called **Logging Time**. This is the time interval in minutes that the app will use for the averages, minimums, maximums and the time span for the graphs. It is planned that this setting will evolve to be more sophisticated, allowing the user to select a logging time for each feature of the app, but this is it for now. In figure 1, the Logging Time and Logging Rate parameters can be spotted.

As well as the **Logging Time**, on the drawer panel you will find the **Logging Rate**, that just affects the tracking section. When you are tracking, all the readings from all the variables will be saved to a local database, that you will be able to export as .csv or .kml format. The **Logging Rate** will dictate how long the app will wait to add another measurement to the database; this could be useful if the user is not interested in registering all data reported by the wind meter, but fewer readings.

3 Data Plots Configuration

Once understood the mechanics of the Data Display configuration and its technical terms, Data Plots are quite straightforward. The variables selectable are basically the same as can be chosen on the Data Displays, with two small differences:

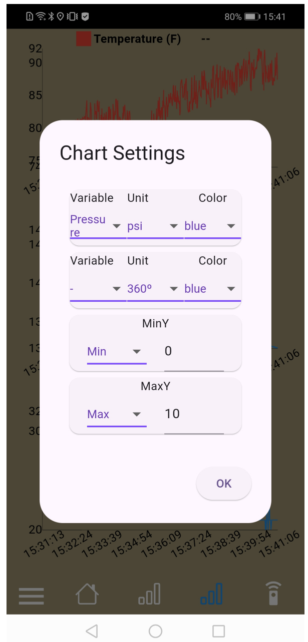

Figure 10: In a similar fashion to how the data displays are configured, you can hold the title of any plot in order to configure it. Here we can choose to display 1 or 2 variables per graph, their units and colours and how the Y-axis range is determined.

1. **Variable Mode**. Here, the Mode is fixed to be always Instantaneous, since it would not make sense plotting the average, minimum or maximum.
2. **Colour**. This new setting tells the plot the plotting colour for the selected variable.
3. **MinY and MaxY**. In order to allow the user to set the Y-axis boundaries, these settings allow the user to choose among four options:
   (a) **Min/Max**: sets the lower/upper limit for the Y-axis as the minimum/maximum of all the plotted variables.
   (b) **MinY1/MaxY1**: sets the lower/upper limit as the min/max of the first plotted variable.
   (c) **MinY2/MaxY2**: sets the lower/upper limit as the min/max of the second plotted variable.
   (d) **Custom**: sets the lower/upper limit for the Y-axis to the value written on the right editable text box.

4 Live Tracking

Anemotracker app also counts with a simple tracking system, so users can record all readings and export them later to analyse. Note that in order for the app to record wind data or environmental data (temperature, humidity and pressure), the user must keep the phone/tablet connected during the whole tracking interval to their Portable or WeatherDot unit. The wind meter does NOT store data, so if the phone is not connected, the wind meter will not keep tracking.

As stated earlier, the tracking system is fairly simple, so it is just made of three parameters or elements:

1. **Logging Rate**. The logging rate is a parameter that tells the data-logger on the app the frequency under which to record the data. For example, if set to 10 seconds, it will just write down 1 value each 10 seconds, and that value will be the latest received.

2. **Tracking Status**: it will be either ON (tracking) or OFF (not tracking). This state is shown and controlled by the switch under 'Live Tracking Menu' section in the Drawer Panel

3. **Tracks**: several tracks can be saved on the phone, but just one is allowed to be tracking at a time. Each track contains within it:

   (a) **Track Name**. The name given to identify the track.

   (b) **Track Description**. In case there is some detailed information to complement the track name.

   (c) **Data**. The track contains several fields, that will add a new value with each value logged by the app. So they can grow indefinitely until the tracking is stopped. The various possible fields are show below. A short description is provided in the fields that have not been explained yet.

      i. **ID**. An identification number for each new recorded set of data.
      ii. **Time**. A temporal reference with the current date and time when the reading was measured ('2024-01-04 15:38:09', for example)
      iii. **Latitude**
      iv. **Longitude**
      v. **Apparent Wind Angle**
      vi. **Apparent Wind Speed**
      vii. **True Wind Angle**
      viii. **True Wind Speed**
      ix. **Velocity Made Good**
      x. **True Wind Direction**
      xi. **Speed**
      xii. **Bearing**
      xiii. **Temperature**
      xiv. **Humidity**
      xv. **Pressure**

5 Data sources and primary variables

Here we will refer to primary variables as those that are directly measured, and in which the derived variables depend on through several equations. Each primary variable comes from a specific data source, that will be one of the following

1. **Wind meter or T/H/P sensor**

   (a) **Ultrasonic Portable**: any compatible wind meter will provide Apparent Wind Angle and Apparent Wind Speed. This is literally the wind that the wind meter perceives.

   (b) **WeatherDot**: temperature, humidity and pressure can be provided by a connected WeatherDot sensor. These are also primary variables, as they are directly measured.

2. **Phone GPS**: the GPS in your phone or tabled provides position and speed data, that can be combined with the apparent wind data to approximate derived variables. The accuracy and reliability will heavily depend on the device used, on the calibration of the internal phone compass or the GPS signal.

3. **Internet**: the app gets the current date and time from the internet, in order to match each measurement with the time at which it was taken. Furthermore, the temperature, humidity and pressure will also be retrieved from here if there is not a WeatherDot connected. In this case, time, temperature, humidity and pressure will be primary variables.

6 True Wind and derived variables calculation

Even when the True Wind determination on the app is not complicated, it is important that our method to compute it is publicly available, so our users can know exactly how it is done and see the method strengths and weaknesses. As in any other computed variable in any other field, there is not a perfect method to get true wind, but there are several levels of accuracy (depending on how many effect we take into account). Therefore, we will state the assumptions, present the equations used and their resolution and, in the end, we will comment the shortcomings of the approximation and why we choose this level of approximation.

For convenience, all vectors will be represented in cylindrical polar coordinates. This means that each vector will be represented by a modulus and an angle. To avoid unleashing imagination, we set the example on an specific real world scenario: sailing. Let say that we are sailing on a boat and the following is true:

1. The wind meter is placed in a way that the real airflow is not modified by the ship geometry and presence. This can be a good approximation if the wind meter is placed wisely.
2. The wind meter is measuring always the wind in a plane, such that is parallel to the ground (the sea surface). This is a good approximation if the sea is calmed, and worsens if the waves grow bigger. Even with some waves this approximation will hold fairly true, in average.
3. The ship moves strictly forward to the direction that the bow is pointing, so drift is not taken into account. This can be a decent approximation on modern ships with very low drift.
4. The wind induced on the wind meter by the movement of the ship is equal in magnitude to the speed of the ship over the ground and of opposite direction. Speed over the ground meaning speed referenced to a static land reference, so this will be different (in general) from the speed of the ship over the water. If the water is almost still (no currents), the speed over the water will match the speed displayed on the app.
5. The bow of the ship, the wind meter 'north' mark and the phone/tablet are aligned, so they all point in the same direction and sense. This is plausible enough and easier to achieve than the other requirements.

Under those conditions, and let s and σ be the module and angle of the wind induced by the speed of the ship; a and α the apparent wind speed and the apparent wind angle; and t and τ the true wind speed and true wind angle. Then, t and τ can be obtained from a, α, s and σ by solving the vector equation in 2D

$$t \sin \tau = a \sin \alpha - s \sin \sigma \qquad \text{X axis} \tag{1}$$

$$t \cos \tau = a \cos \alpha - s \cos \sigma \qquad \text{Y axis} \tag{2}$$

To isolate the modulus and the angle apart, the classic trick of doing $(1)^2 + (2)^2$ and $(1)\,/\,(2)$ can be used. This means adding the two equations squared and dividing the first by the second. $(1)^2 + (2)^2$ gives

$$t^2 \left(\sin^2 \tau + \cos^2 \tau\right) = (a \sin \alpha - s \sin \sigma)^2 + (a \cos \alpha - s \cos \sigma)^2 \iff$$

$$\iff t^2 = (a \sin \alpha)^2 + (s \sin \sigma)^2 - 2a \sin \alpha s \sin \sigma + (a \cos \alpha)^2 + (s \cos \sigma)^2 - 2a \cos \alpha s \cos \sigma \iff$$

$$\iff t^2 = a^2 + s^2 - 2as\,(\sin \alpha \sin \sigma + \cos \alpha \cos \sigma)$$

therefore

$$t = \sqrt{a^2 + s^2 - 2as\,(\sin \alpha \sin \sigma + \cos \alpha \cos \sigma)}$$

Dividing equations $(1)\,/\,(2)$,

$$\tau = \arctan\left(\frac{a \sin \alpha - s \sin \sigma}{a \cos \alpha - s \cos \sigma}\right)$$

In present case, as the X axis is aligned with the speed, $\sigma_X = 0 \implies \sin \sigma_X = 0$ and $\cos \sigma_X = 1$. So it gets simplified to

$$\boxed{\text{TWS} \equiv t = \sqrt{a^2 + s^2 - 2as \cos \alpha} \qquad \text{TWA} \equiv \tau = \arctan\left(\frac{a \sin \alpha}{a \cos \alpha - s}\right)} \tag{3}$$

And, to make things even simpler, once computed τ (therefore known), t can also be obtained as

$$t \sin \tau = a \sin \alpha - s \underbrace{\cancel{\sin \sigma}}_{0} \iff \boxed{\text{TWS} \equiv t = \frac{a \sin \alpha}{\sin \tau}} \tag{4}$$

6.0.1 Additional derived variables

The True Wind Angle and True Wind Speed are now know, as seen in equations 3 and 4. From this new starting point it is direct to get all the remaining variables

- **TWD**: we just need to change the angle reference, so the angle is measured from the magnetic north, instead of the bow of the ship (that matches the 'north' mark of the wind meter and where the phone/tablet is pointing). Therefore, the current heading of the ship σ is added to the True Wind Angle, yielding the True Wind Direction

$$\mathrm{TWD} = \mathrm{TWA} + \sigma$$

- **CWS**: the Apparent Wind Speed is projected on the direction perpendicular to which the wind meter points in, resulting in the Crosswind component. Apparent Wind is taken instead of True Wind because this variable is usually of interest in stationary scenarios, so apparent wind is the same as the true wind.

$$\mathrm{CWS} = \mathrm{AWS} \cdot \sin\left(\mathrm{AWA} + 180\right)$$

  The projection should be done with $\cos\theta$, being θ the laid by the direction from where the wind comes and the direction in which the wind meter is pointing. We substituted it by the relation $\cos\theta = \sin(\mathrm{AWA})$, knowing that AWA and θ are complementary angles. Furthermore, an extra 180 phase is added, so we project the sign of the vector towards where the wind goes, not from where it comes.

- **VMG**: in an analogous way to how CWS was computed, VMG is the projected component of the speed of the ship s on the wind direction (the true wind direction)

$$\mathrm{VMG} = s \cdot \cos\left(\mathrm{TWA}\right)$$

  As it can be seen, it will be positive when advancing upwind, and negative when sailing downwind. Often it is interesting to maximise VMG to get to specific points situated upwind the fastest possible, as the direction VMG will be, in general, different for different ships and situations.

7 Additional Features

The main functionalities and features have already been discussed and detailed, but there are some minor features, available on the Drawer Panel, that will be commented along this section.

7.1 Reconnection

If the Bluetooth connection with the Portable wind meter or the WeatherDot is lost due to an external factor (anything else than pushing the 'Unpair ...' button), the reconnection feature will come into play. If the reconnection interval is set to a non-zero value, via the slider on the Connection Menu section of the Drawer Panel, the phone will attempt to connect again to the last device during the time set on the reconnection interval. If connection is not achieved in that time, it will just give up.

7.2 Logging Time

The logging time is a global parameter of the app that controls how many measurements the app should keep in RAM memory. It can be set on the Drawer Panel and tells the app to store all measurements up to the ones that are older than the Logging Time parameter. Measurements that were taken before the Logging Time interval, will be discarded and forgotten. All the measurements that fall into the logging time interval are the ones shown in plots and the ones on which the averages, minimums and maximums are computed.

7.3 Wind Settings

The wind settings section contains some parameters that can affect how the wind data received is processed or displayed. These can be aspects like a heavier filtering or some offset or correction of the measurements.

1. **Bow offset**. This parameter controls the angle offset that will be added to the Apparent Wind Angle readings received. This helps the user to fine-tune the alignment of the wind meter remotely. Since the wind meters are frequently placed high up on a pole or similar, it can be hard to perfectly position the wind meter pointing in the desired position, so this offset can correct that misalignment without reinstalling the wind meter.