

## How the WeatherStation® Instrument Works

### *About the Ultrasonic Wind Sensor*

The ultrasonic wind sensor (an ultrasonic anemometer) measures apparent wind speed and direction. The WeatherStation Instrument contains four ultrasonic transducers, visible through the four holes in the top of the sensor's wind channel (see Figure 1). These transducers operate in pairs—one transducer injects a pulse into the air. The pulse bounces off the metal plate at the bottom of the wind channel and is carried by the wind to arrive at the listening transducer a short time later.

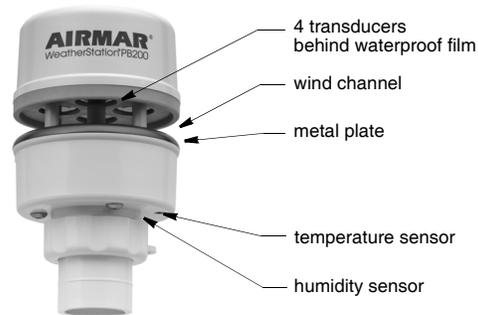


Figure 1. WeatherStation ultrasonic wind sensor

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When there is no wind, the pulse travels at the speed of sound from the sender to the receiver. Whenever the wind is blowing in that direction, the pulse will arrive sooner than if the air is still. Similarly, whenever the wind is blowing in the opposite direction, the pulse will arrive later than if the air is still. The four transducers take turns in sending and receiving pulses.

A microprocessor within the WeatherStation Instrument then combines the measurements from all four transducers to calculate the resultant wind speed and direction. Throughout this process, the sensor monitors the air temperature, to compensate for the fact that the speed of sound in air changes with temperature.

### *Understanding True and Apparent Wind*

The WeatherStation Instrument has the unique ability to display both *true* and *apparent* wind. *True* wind is the actual motion of the air relative to the earth. *Apparent* wind is the wind which an observer experiences while moving or on board a vessel/vehicle. It is the result of two motions—the actual motion of the air (the true wind) and the motion of the vessel /vehicle. If the vessel/vehicle is not moving, then the true and apparent wind will be the same.

There are two components to any wind measurement: speed and direction. By convention, the wind direction is an angle representing the direction *from* which the wind is blowing. Sometimes this angle is referenced to true or magnetic north, and sometimes it is referenced to the front of the vessel / vehicle. Both true and apparent wind use these same references.

Consider the case of a vessel/vehicle proceeding at a speed of 15 MPH in calm air. An observer on board would experience a wind of 15 MPH from dead ahead. This *apparent* wind would be due solely to the motion of the vessel/ vehicle. If a *true* wind of 15 MPH was blowing from the rear, an observer would experience dead calm—no *apparent* wind. That is because the vessel/vehicle is moving at the same speed and in the same direction as the surrounding air.

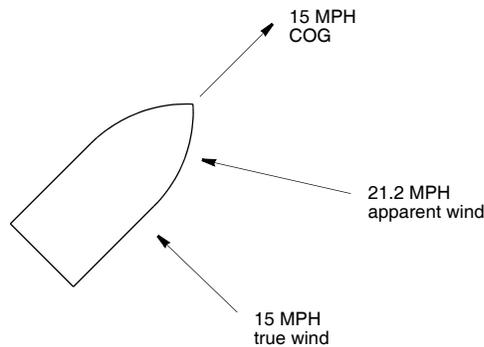


Figure 2. Apparent wind

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Now, consider the more complicated situation of a vessel/vehicle proceeding at 15 MPH with a *true* wind of 15 MPH blowing from the side (see Figure 2). To an observer on board, the *apparent* wind would be 21.2 MPH blowing from an angle 45° off the front.

In order to calculate the true wind speed and direction when on board a moving vessel/vehicle, it is necessary to know the apparent wind speed and direction, the speed and course over ground of the vessel/vehicle, the compass heading, and the local magnetic variation. Note that heading and course are not the same thing: heading is the direction the front of the vessel/vehicle is pointing, while course is the direction the vessel/vehicle is traveling. Heading and course may differ due to the effects of wind and/or current. The WeatherStation Instrument can provide true wind speed and direction only if all of the data is available. The speed and course over ground must be provided by a GPS receiver—either built-in or networked. The heading may be provided by either the built-in electronic compass or by an external networked compass.

Because true wind is calculated using the data from several sensors, its accuracy depends on the accuracy of all the raw data used in the calculation. For instance, if the electronic compass is located near iron or a similar magnetic disturbance, the heading will be incorrect, and the true wind calculation will therefore be in error, perhaps by quite a bit. In another example, the speed and course over ground provided by the GPS receiver are averaged over time. If the vessel / vehicle is performing maneuvers, changing speed and/or direction, then it will take a few seconds for the SOG and COG values to "catch up". The reported true wind values will therefore also be incorrect until the vessel/vehicle reaches a steady-state condition, traveling in a straight line at a constant speed.

### ***About the Electronic Compass***

The WeatherStation Instrument includes three magnetoinductive sensors that measure magnetic field-strength in three axes relative to the instrument. From combined measurements of the three-axis magnetic and tilt sensors, it calculates the resultant magnetic heading angle, thereby providing a built-in three-axis electronic compass.

Like all magnetic compasses, the WeatherStation compass will be affected by any ferrous or magnetic materials in the vicinity, such as metal structures, motors, speakers, etc. It will also be affected by nearby electric fields, such as the wiring for navigation lights or radar domes. These nearby sources of magnetic interference will distort the magnetic field and produce errors in the compass heading. These errors are known as magnetic deviation.

### ***About Magnetic Variation and True Heading***

The earth acts like a giant magnet, with a magnetic north pole and a magnetic south pole. The axis of the magnetic poles is offset approximately 11.5° from the axis of the earth's rotation. Therefore, the earth's magnetic north and south poles are in different locations than the earth's geographic north and south poles. In addition, the earth's magnetic field is non-uniform, and changes over time. Magnetic variation, also known as magnetic declination, is the angle between magnetic north and true (or geographic) north, at the observer's current location.

A magnetic compass measures heading with respect to magnetic north. To convert this magnetic heading to true heading (that is, heading with respect to true north), the magnetic variation must be added to the measured magnetic heading value.

Because magnetic variation changes with location and gradually over time, it is necessary to calculate the magnetic variation using the user's present position and the current date. Therefore it is necessary to have a GPS with a fix in order to provide magnetic variation and heading with respect to true north.

### ***About the Air Temperature Sensor***

The WeatherStation Instrument includes a built-in negative-temperature-coefficient thermistor that measures the ambient air temperature. This NTC thermistor is located in a thermally isolated region of the WeatherStation housing that is open to the outside air. See Figure 1)

### ***About Wind Chill Temperature***

Wind Chill is a term that describes the heat loss on the human body resulting from the combined effects of low temperature and wind. As wind speed increases, heat is carried away from the body at a faster rate, causing a reduction in skin temperature. Because the face is the part of the human body that is most likely to be exposed, the wind-chill index is adjusted for the average adult face.

The concept of wind chill does not apply to inanimate objects, such as a vessel / vehicle. The only effect that wind chill has in this case is to shorten the time it takes the object to cool to the actual air temperature—wind chill does not cause an object to cool below that temperature. For example, fresh water freezes at 0°C (32°F) regardless of what the wind chill is.

The WeatherStation Instrument calculates two values for wind-chill temperature: one using the apparent wind-speed, and one using the true wind-speed. The *apparent* wind-chill temperature is relevant to what an observer is currently experiencing on the vessel/vehicle. The *true* wind-chill temperature indicates what the wind chill would be if the vessel/vehicle were not moving.

Wind chill temperature is only defined for temperatures at or below 10°C (50°F) and wind speeds above 3MPH.

By default, transmission of wind-chill data is disabled by the WeatherStation Instrument. When used with WeatherCaster software, the wind-chill data will be automatically enabled.

### ***About the Barometric Pressure Sensor***

The WeatherStation Instrument contains a temperature-compensated, silicon, piezoresistive, pressure sensor. It measures atmospheric pressure for use as a digital barometer. While a single measurement of air pressure at a given location has little value, the trend of changing pressure and wind over time can be a useful tool in performing basic weather forecasting.

### ***About the GPS***

Some WeatherStation Instruments have a built-in Global Positioning System with their own antenna, receiver, and position determining electronics. The GPS receiver receives radio signals from a constellation of orbiting satellites maintained by the U.S. government. By accurately measuring the time it takes for a transmission to travel from each satellite to the receiver, the unit is able to determine the distance between the satellite and the receiver. When the distance is known to three satellites, the unit is able to calculate the latitude and longitude of the receiver. This is known as a 2D fix. If the distance is known to four or more satellites, then the unit is additionally able to calculate the altitude of the receiver. This is known as a 3D fix.

The GPS receiver in the WeatherStation Instrument takes approximately one minute on average to achieve a position fix after power is first applied. This is known as the "time to first fix."

The GPS receiver synchronizes itself to the atomic clocks on board each satellite. This allows the GPS receiver to accurately determine the date and time as well.

If the GPS receiver is mounted on a moving vessel/vehicle, its changing position over time allows the speed and course over ground to be calculated. The course reported by a GPS is always with respect to true north.

The ability of the WeatherStation Instrument to calculate true wind speed and direction depends on the presence of a GPS fix. If the GPS receiver is not tracking at least three satellites, then the WeatherStation Instrument will be unable to provide true wind data. (Apparent wind data should always be available, regardless of the status of the GPS receiver.)

Certain models of the WeatherStation Instrument do not include a built-in GPS receiver. In this case, if the true wind capabilities of the WeatherStation Instrument are desired, it will be necessary to connect the output from an external NMEA 0183-capable GPS to the NMEA input on the WeatherStation Instrument (or to the optional Combiner), in order to enable the true wind capabilities of the WeatherStation Instrument.

Even if your WeatherStation Instrument includes a built-in GPS receiver, you may wish to use a separate external GPS receiver instead, for the determination of true wind. If the WeatherStation Instrument receives speed over ground and course over ground (SOG and COG) data on its NMEA input from an external GPS, these data will override the data from the built-in GPS for the purpose of calculating true wind speed and direction. In addition, the WeatherStation Instrument will automatically suppress transmission of GPS messages from its own built-in GPS receiver.

### ***About True Wind Relative to Water***

If a fix from a GPS receiver is not available, it is still possible for the WeatherStation Instrument to determine a value for true wind, if the speed of the vessel through the water is known. In this case, it is necessary that a water-speed sensor with an NMEA output (such as an Airmar Smart™ Sensor) be connected to the NMEA input on the WeatherStation Instrument (or to the optional Combiner).

The WeatherStation Instrument's calculation for true wind relative to water makes the significant simplifying assumption that the vessel's course is the same as its heading. That is, the effects of wind and current on the motion of the vessel are ignored. The direction of the true wind relative to water is referenced only to the bow of the vessel, not to true or magnetic north.