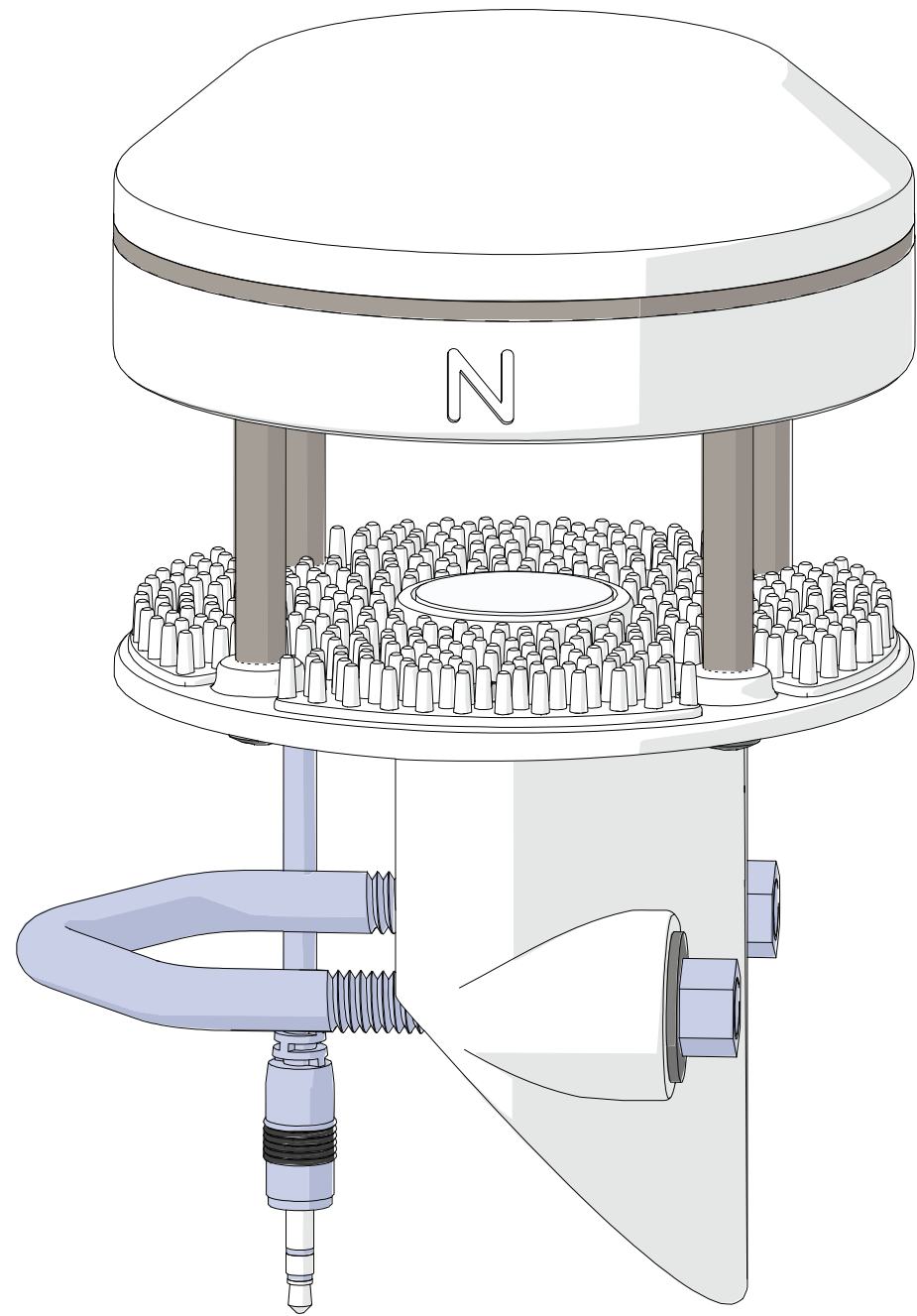


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## INTRODUCTION

### 1. INTRODUCTION

Thank you for choosing the ATMOS 22 Ultrasonic Anemometer from METER Group.

The ATMOS 22 Ultrasonic Anemometer is designed for continuous monitoring of wind speed and direction ([Section 3](#)). A robust, no moving parts design that prevents errors because of wear or fouling make the ATMOS 22 ideal for long-term, remote installations.

Applications of the ATMOS 22 are listed below:

- Weather monitoring
- Microenvironment monitoring
- In-canopy wind measurement
- Spatially-distributed environmental monitoring
- Wind profiling
- Crop weather monitoring
- Weather networks

Additional advantages include its low-power design that supports battery-operated data loggers, and the SDI-12 three-wire interface. A tilt sensor warns the user of out-of-level condition, and no configurations are necessary.

## 2. OPERATION

Please read all instructions before operating the ATMOS 22 to ensure it performs to its full potential.

### SAFETY PRECAUTIONS

METER sensors are built to the highest standards. Misuse, improper protection, or improper installation may damage the sensor and possibly void the manufacturer’s warranty. Before integrating ATMOS 22 or other METER sensors into a system, make sure to follow the recommended installation instructions and have the proper protections in place to safeguard sensors from damage.

## 2.1 INSTALLATION

Follow the steps listed in [Table 1](#) to set up the ATMOS 22 and start collecting data.

**Table 1 Installation**

<b>Tools Needed</b>	<p><b>Wrench</b> 13 mm (1/2 inch)</p> <p><b>Secure mounting location</b></p> <p><b>Mount</b> meteorological stand pole in cement tripod</p> <p>Diameter: 31.8–50.8 mm, 1.25–2.00 inch</p> <p><b>NOTE:</b> Smaller mounts are compatible if washers are added to the V-bolt (not included). Standard pipe sizes that are compatible are 1.00-, 1.25-, and 1.50-inch diameter pipes. Square tubing with a width of 1.25 to 2.00 inches or T-posts can also work as mounting options.</p>
<b>Preparation</b>	<p><b>Consider the Surroundings</b> Avoid obstructions. Ensure that site selection is far from wind obstruction.</p> <p><b>Conduct System Check</b> Verify that the ATMOS 22 reads within expected ranges (<a href="#">Section 3</a>).</p> <p><b>Adjust Pole Height</b> Mounting height can be adjusted based on the specific application for the ATMOS 22.</p>

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## REFERENCES

Campbell GS, Unsworth MH. 1979. An inexpensive sonic anemometer for eddy correlation. *J Appl Meteor.* 18:1072–1077.

Table 1 Installation (continued)

<p><b>Mounting</b></p>	<p><b>Install on Mounting Pole</b> The ATMOS 22 is fitted with a V-bolt, allowing it to be mounted on top of most posts, poles, tripods, etc.</p> <p><b>Mount Toward True North</b> The ATMOS 22 must be oriented correctly for accurate wind direction measurements. An <b>N</b> engraved on the side of the instrument should be oriented to point true north (not magnetic north).</p> <p><b>Level the System</b> Use the bubble level underneath the ATMOS 22 or a ProCheck display to level the anemometer. The angle of the mounting pole may need to be adjusted or shims added to the ATMOS 22 pole interface to achieve level.</p> <p><b>Secure the System</b> Use a wrench to tighten the bolts, securing the ATMOS 22 flat and tight against the top of the stand.</p>
<p><b>Connecting</b></p>	<p><b>Plug Sensor into Data Acquisition System</b> Connect the 3.5-mm stereo plug connector into a ZENTRA-, EM60-, or Em50-family of data loggers. Configure it to read the ATMOS 22 (refer to <a href="#">Section 3</a>).</p> <p><b>Verify</b> Use the SCAN function in the software to show a list of ATMOS 22 readings. Verify that these readings are within expected ranges.</p> <p><b>Third Party Data Loggers</b> To connect to a non-METER data logger, see the <a href="#">ATMOS 22 Integrator Guide</a>.</p>

**Table 1 Installation (continued)**

<b>Protecting Cables</b>	Improperly protected cables can lead to severed cables or disconnected sensors. Cabling issues can be caused by many factors such as rodent damage, driving over sensor cables, tripping over the cable, not leaving enough cable slack during installation, poor sensor wiring connections.
	<p><b>Relieve Cable Strain</b></p> <p>To relieve strain on the connections and prevent loose cabling from being inadvertently snagged, gather and secure the cables travelling between the ATMOS 22 and the data acquisition device to the mounting mast in one or more places.</p>
	<p><b>Prevent Rodent Damage</b></p> <p>Install cables in conduit or plastic cladding when near the ground to avoid rodent damage.</p>
	<p><b>Secure Excess Cable</b></p> <p>Tie excess cable to the data logger mast to ensure cable weight does not cause sensor to unplug.</p>

## 2.2 CONNECTING THE ATMOS 22

The ATMOS 22 Ultrasonic Anemometer works most efficiently with ZENTRA-, EM60-, or Em50-family data loggers. However, this system will not work with legacy data loggers (Decagon Em5, Em5B).

### 2.2.1 CONNECTING TO A ZENTRA, EM60, OR EM50 FAMILY DATA LOGGER

The ATMOS 22 works seamlessly with ZENTRA, EM60, or Em50 data loggers. Logger configuration may be done using either ZENTRA Utility (desktop and mobile) or ZENTRA Cloud (for cell-enabled ZENTRA data loggers).

1. Plug the 3.5-mm stereo plug connector into one of the sensor ports.
2. Once the ATMOS 22 has been connected to a ZENTRA, EM60, or Em50 data logger, configure the logger port for the ATMOS 22.
3. Set the measurement interval.

Download ATMOS 22 data from a ZENTRA, EM60, or Em50 logger using either ZENTRA Utility or ZENTRA Cloud.

The standard station with a 3.5-mm stereo plug connector (Figure 1) connects to and is configured with a ZENTRA, EM60, or Em50 data logger.

**WARRANTIES.** The Seller warrants all equipment manufactured by it to be free from defects in parts and labor for a period of one year from the date of shipment from factory. The liability of the Seller applies solely to repairing, replacing, or issuing credit (at the Seller's sole discretion) for any equipment manufactured by the Seller and returned by the Buyer during the warranty period. SELLER MAKES NO SEPARATE OR OTHER WARRANTY OF ANY NATURE WHATSOEVER, EXPRESS OR IMPLIED, INCLUDING THE WARRANTY OF MERCHANTABILITY OR FOR A PARTICULAR PURPOSE. There shall be no other obligations either expressed or implied.

**LIMITATION OF LIABILITY.** Seller will not be liable to the Buyer or any other person or entity for indirect special, incidental, consequential, punitive, or exemplary damages in connection with this transaction or any acts or omissions associated therewith or relating to the sale or use of any goods, whether such claim is based on breach of warranty, contract, tort, or other legal theory and regardless of the causes of such loss or damages or whether any other remedy provided herein fails. In no event will the Seller's total liability under this contract exceed an amount equal to the total amount paid for the goods purchased hereunder.

**WAIVER.** In the event of any default under or breach of the contract by the Buyer, the Seller has the right to refuse to make further shipments. The Seller's failure to enforce at any time or for any period of time the provisions of this contract will not constitute a waiver of such provisions or the right of the Seller to enforce each and every provision.

**GOVERNING LAW.** The validity, construction, and performance of the contract and the transactions to which it relates will be governed by the laws of the United States of America. All actions, claims, or legal proceedings in any way pertaining to this contract will be commenced and maintained in the courts of Whitman County, State of Washington, and the parties hereto each agree to submit themselves to the jurisdiction of such court.

**SEVERABILITY.** If any of the Terms and Conditions set out in this contract are declared to be invalid by a court, agency, commission, or other entity having jurisdiction over the interpretation and enforcement of this contract, the applications of such provisions to parties or circumstances other than those as to which it is held invalid or unenforceable will not be affected. Each term not so declared invalid or unenforceable will be valid and enforced to the fullest extent permitted by law and the rights and obligations of the parties will be construed and enforced as though a valid commercially reasonable term consistent with the undertaking of the parties under the order has been substituted in place of the invalid provision.

**SET-OFF.** The Buyer may not set-off any amount owing from the Seller to the Buyer against any amount payable by the Buyer to the Seller whether or not related to this contract

#### 4.5 TERMS AND CONDITIONS

**CONTRACT FORMATION.** All requests for goods and/or services by METER Group, Inc. USA (METER) are subject to the customer's acceptance of these Terms and Conditions. The Buyer will be deemed to have irrevocably accepted these Terms and Conditions of Sale upon the first to occur of the Buyer's issuance of a purchase order or request for goods or services. Unless expressly assented to in writing by METER, terms and conditions different are expressly rejected. No course of dealing between the parties hereto shall be deemed to affect or to modify, amend, or discharge any provisions of this agreement.

**PRICES AND PAYMENT.** Invoice prices will be based upon METER prices as quoted or at METER list price in effect at the time an order is received by the Seller. Prices do not include any state or federal taxes, duties, fees, or charges now or hereafter enacted applicable to the goods or to this transaction, all of which are the responsibility of the Buyer. Unless otherwise specified on the invoice, all accounts are due and payable 30 days from the date of invoice. Unpaid accounts extending beyond 30 days will be subject to a service charge of 2% per month (24% per annum). Should Seller initiate any legal action or proceeding to collect on any unpaid invoice, Seller shall be entitled to recover from Buyer all costs and expenses incurred in connection therewith, including court costs and reasonable attorney's fees.

**RISK OF LOSS AND DELIVERY TITLE.** Liability for loss or damage passes to the Buyer when the Seller delivers the goods on the Seller's dock or to the transporting agent, whichever occurs first. The Seller has the right to deliver the goods in installments. Shipping and delivery dates communicated by the Seller to the Buyer are approximate only.

**SHIPMENT.** In the absence of specific shipping instructions, the Seller, if and as requested by the Buyer, will ship the goods by the method the Seller deems most advantageous. Where the Seller ships the goods, the Buyer will pay all transportation charges that are payable on delivery or, if transportation charges are prepaid by the Seller, the Buyer will reimburse the Seller upon receipt of an invoice from the Seller. The Buyer is obligated to obtain insurance against damage to the goods being shipped. Unless otherwise specified, the goods will be shipped in the standard Seller commercial packaging. When special packing is required or, in the opinion of the Seller, required under the circumstances, the cost of the special packaging shall be the responsibility of the Buyer.

**INSPECTION AND ACCEPTANCE.** Goods will be conclusively deemed accepted by the Buyer unless a written notice setting out the rejected goods and the reason for the rejection is sent by the Buyer to the Seller within 10 days of delivery of the goods. The Buyer will place rejected goods in safe storage at a reasonably accessible location for inspection by the Seller.

**CUSTOM GOODS.** There is no refund or return for custom or nonstandard goods.



Figure 1 3.5-mm stereo plug connector wiring

The ATMOS 22 comes standard with a 5-m cable. It may be purchased with custom cable lengths for an additional fee (on a per-meter fee basis). METER has successfully tested digital communication on cable lengths up to 1,000 m (3,200 ft). This option eliminates the need for splicing the cable (which introduces a possible failure point). However, the maximum recommended length is 75 m.

#### 2.2.2 CONNECTING TO A NON-METER LOGGER

The ATMOS 22 ultrasonic anemometer may be purchased for use with non-METER data loggers. These sensors typically come configured with stripped and tinned (pigtail) lead wires for use with screw terminals. Refer to the third-party logger manual for details on wiring. The [ATMOS 22 Integrator Guide](#) gives detailed instructions on connecting the anemometer to non-METER loggers.

Connect the ultrasonic anemometer wires to the data logger as illustrated in [Figure 2](#), with the power supply wire (brown) connected to the excitation, the digital out wire (orange) to a digital input, and the bare ground wire to ground.

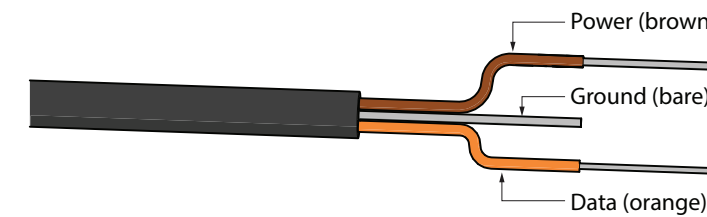


Figure 2 Pigtail wiring

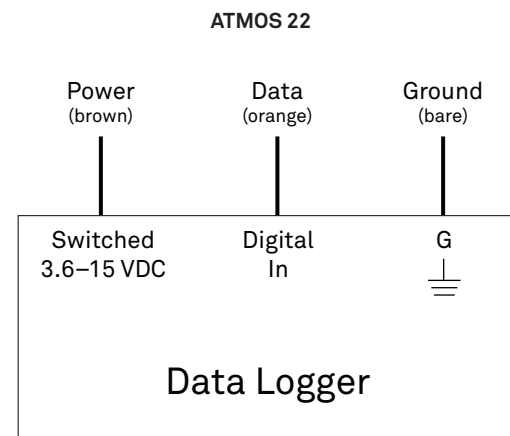


Figure 3 Wiring diagram

**NOTE:** The acceptable range of excitation voltages is from 3.6 to 15.0 VDC. To read the ATMOS 22 with Campbell Scientific data loggers, power the sensors off a 12 V port or switched 12 V port.

If the ATMOS 22 has a standard 3.5-mm plug and will be connected to a non-METER data logger, please use one of the following two options when connecting to a non-METER data logger.

**Option 1**

1. Clip off the plug on the sensor cable.
2. Strip and tin the wires.
3. Wire it directly into the data logger.

This option has the advantage of creating a direct connection with no chance of the sensor becoming unplugged. However, it then cannot be easily used in the future with a METER readout unit or data logger.

**Option 2**

Obtain an adapter cable from METER.

The adapter cable has a connector for the stereo plug connector on one end and three wires (or pigtail adapter) on the other end for connection to a data logger. Both the stripped and tinned adapter cable wires have the same termination as in Figure 3; the brown wire is excitation, the orange is output, and the bare wire is ground.

**2.3 COMMUNICATION**

The ATMOS 22 communicates using the SDI-12 communication protocol. To obtain detailed instructions, refer to the [ATMOS 22 Integrator's Guide](#).

**SERVICE**

**4.4 CUSTOMER SUPPORT**

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 8 am–5 pm Pacific time.

**Email:** support.environment@metergroup.com  
sales.environment@metergroup.com

**Phone:** +1.509.332.5600

**Fax:** +1.509.332.5158

**Website:** [www.metergroup.com](http://www.metergroup.com)

If contacting METER by email or fax, please include the following information:

<i>Name</i>	<i>Email address</i>
<i>Address</i>	<i>Instrument serial number</i>
<i>Phone</i>	<i>Description of the problem</i>

**NOTE:** For ATMOS 22 Ultrasonic Anemometer purchased through a distributor, please contact the distributor directly for assistance.



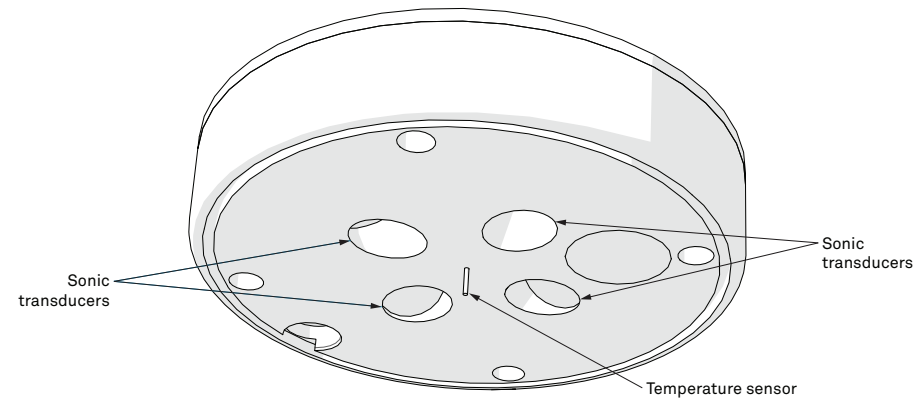


Figure 6 Temperature needle and sonic transducers

### 4.3 TROUBLESHOOTING

Table 2 Troubleshooting the ATMOS 22

Problem	Possible Solutions
ATMOS 22 not responding	<ul style="list-style-type: none"> <li>Check power to the sensor.</li> <li>Check sensor cable and 3.5-mm plug integrity.</li> <li>Check data logger wiring to ensure the following connections: Brown—3.6 VDC to 15 VDC power supply Orange—digital out Bare—ground</li> <li>If sensor does not respond, use the ProCheck to make sure it is working satisfactorily.</li> </ul>
No wind speed	<ul style="list-style-type: none"> <li>Check anemometer pathway to make sure there is no debris blocking the path of the sonic transducer measurement (between transducers and polished metal on base).</li> <li>Check the sonic transducers to make sure that there is no water buildup; if there is moisture, take a dry cloth and dab it away.</li> <li>Check to see if the acoustic mirror (Figure 4) is dirty, and clean by flushing with water and dry with a dry cloth (Section 4.2).</li> <li>Be sure the ATMOS 22 is level.</li> </ul>

## 3. SYSTEM

This section describes the ATMOS 22 ultrasonic anemometer.

### 3.1 SPECIFICATIONS

#### Measurement Specifications

##### Horizontal Wind Speed

Range:	0–30 m/s
Resolution:	0.01 m/s
Accuracy:	The greater of 0.3 m/s or 3% of measurement

##### Wind Gust

Range:	0–30 m/s
Resolution:	0.01 m/s
Accuracy:	The greater of 0.3 m/s or 3% of measurement

##### Wind Direction

Range:	0°–359°
Resolution:	1°
Accuracy:	±5°

##### Tilt

Range:	0°–180°
Resolution:	0.1°
Accuracy:	±1°

##### Dimensions

10 cm diameter × 16 cm height

##### Cable Length

5 m (custom cable lengths are available for an additional cost)

**Electrical and Timing Characteristics**

Supply Voltage (VCC) to GND	
Minimum	3.6 VDC continuous
Typical	
Maximum	15.0 VDC continuous
Digital Input Voltage (logic high)	
Minimum	2.8 V
Typical	3.0 V
Maximum	15.0 V
Digital Input Voltage (logic low)	
Minimum	-0.3 V
Typical	0.0 V
Maximum	0.8 V
Power Line Slew Rate	
Minimum	1.0 V/ms
Typical	
Maximum	
Current Drain (during measurement)	
Minimum	0.050 mA
Typical	0.125 mA
Maximum	0.500 mA
Current Drain (while asleep)	
Minimum	0.050 mA
Typical	0.125 mA
Maximum	0.150 mA
Operating Temperature Range	
Minimum	-40 °C
Typical	
Maximum	50 °C

**4. SERVICE**

This section contains calibration frequencies, cleaning and maintenance, troubleshooting guidelines, and contact information..

**4.1 CALIBRATION**

The relationship between wind speed and phase is determined by geometry and the laws of physics. Since the geometry is tightly controlled in manufacture, no individual anemometer calibration is needed. The phase of each ATMOS 22 anemometer is initially set to zero in a zero wind speed condition. Extensive wind tunnel and field testing has shown this to result in accurate wind speed measurements. A subsample of anemometers is checked monthly for accuracy as part of routine QA/QC (quality assurance) procedures. Routine recalibration of the ATMOS 22 is not necessary.

**4.2 CLEANING AND MAINTENANCE**

Below are instructions to clean and maintain the ATMOS 22. Cleaning and maintenance should be performed as needed.

1. Make sure nothing is obscuring the temperature sensor or the sonic transducers shown in [Figure 6](#) (cobwebs, leaves, wasp nests, etc.).
2. Check the following areas to make sure they are clear of miscellaneous environmental, animal (specifically bird droppings), insect debris, or spider webs:
  - a. Anemometer opening
  - b. Sintered glass reflection plate
3. Clean the ATMOS 22
  - a. Scrub with light to medium pressure using a warm, damp cloth.
  - b. Completely dry the instrument by removing excess water using a dry cloth.
  - c. Clean around posts and between crevices using a dry brush.
  - d. Be sure the sensor is level after cleaning.

**CAUTIONS**

- **DO NOT** immerse the sensor in water.
- **DO NOT** touch the temperature sensor needle ([Figure 6](#)).
- Avoid more than light pressure on the sonic transducers ([Figure 6](#)).

**NOTE:** Do not allow water to enter the ultrasonic sensors ([Figure 6](#)). Water may corrode the metal parts inside the sensors and ruin them. Do not touch the temperature sensor when cleaning because it is very delicate and can be damaged if pushed into the ATMOS 22 body.

ATMOS 22

$$S = \sqrt{\overline{u^2} + \overline{v^2}} \quad \text{Equation 7}$$

Where the overbar indicates an average of the values sampled every 10 s, wind direction is computed with Equation 8.

$$\theta = \tan^{-1}(\overline{v}/\overline{u}) \quad \text{Equation 8}$$

The wind measurement requires 42 ms to complete. An additional 60 ms are required for the computations to determine phase differences. The anemometer samples every 10 s (or more often if requested through more frequent SDI-12 commands). The gust speed reported is the highest instantaneous wind speed measured during the selected averaging interval (must be >20 s or gusts will equal speed). Wind speeds above 30 m/s are not measured reliably with the phase shift method, so wind speeds measured above 30 m/s will be reported as 30 m/s.

**NOTE:** Cup anemometers average over a much longer interval than 42 ms, so the gusts measured with a sonic anemometer will have a larger peak-to-mean ratio than a cup anemometer.

### 3.6 LIMITATIONS

The ATMOS 22 is engineered to be a robust device with minimal downtime. However, it does have limitations that will affect its measurements under some conditions.

#### 3.6.1 SNOW AND ICE ACCUMULATION

Accumulation of snow, ice, or frost can compromise the wind measurements if accumulation occurs in the anemometer acoustic pathway or on the acoustic mirror (see Section 4.2).

#### 3.6.2 HEAVY RAIN AND STRONG WIND

During strong storm events, water can splash off of the horizontal bottom plate of the anemometer envelope and interrupt the signal passing between the sonic transducers. The spikes on the bottom plate help dissipate the energy of rainwater to minimize splashing and reduce the likelihood that the wind measurements are interrupted. Additionally, porous polyethylene membranes protect the ultrasonic transducers from direct splashing and the sintered (porous) glass construction draws water from the upper surface of the plate to keep a constant sound path length. Despite these features, heavy rain and strong wind can still cause water to reach the membranes and also cause temporary water buildup on the sintered glass. The hydrophobic nature of the transducer protective membranes and the quick-draining ability of the sintered glass should limit wind measurement interruptions to heavy rain events and should bring wind measurement back online soon after extreme conditions abate.

SYSTEM

#### Power Up Time (SDI Ready)—aRx! Commands

Minimum	
Typical	10 s
Maximum	

#### Power Up Time (SDI Ready)—Other Commands

Minimum	
Typical	800 ms
Maximum	

#### Measurement Duration

Minimum	
Typical	110 ms
Maximum	3,000 ms

#### Compliance

Manufactured under ISO 9001:2015
EM ISO/IEC 17050:2010 (CE Mark)

### 3.2 ANEMOMETER

The open space in the center of the anemometer is where the ATMOS 22 measures wind speed. Ultrasonic signals emitted from transducers at right angles to each other bounce off the porous sintered glass plate (Figure 4) and back up to the opposite sensor. The speed of sound is affected by the wind, and the wind speed is calculated by measuring differences in the time it takes for sound to travel back and forth between sensors (Section 3.5).

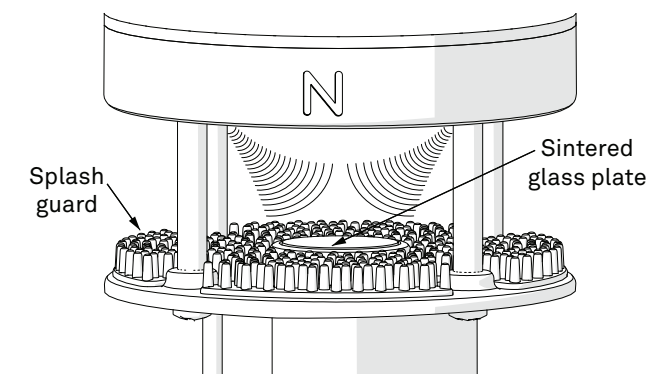


Figure 4 Anemometer

### 3.3 TEMPERATURE SENSOR

The ATMOS 22 temperature measurement (Figure 5) is made in the small stainless steel needle containing a tiny temperature sensor (thermistor) that extends from the middle of the four ultrasonic transducers in the center of the anemometer. The speed of sound is temperature dependent, so the ATMOS 22 temperature measurement is important for the wind speed and direction calculations. The ATMOS 22 temperature measurement should not be used as an accurate measurement of air temperature. Testing has shown errors of as much as 2 °C between the ATMOS 22 temperature sensor and the true air temperature under sunny conditions.

NOTE: Temperature data will not be collected by legacy Em50 series data loggers.

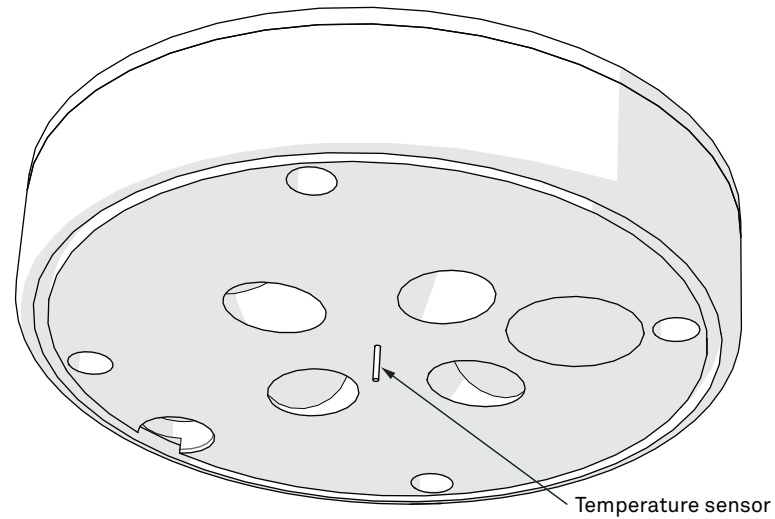


Figure 5 Temperature sensor

### 3.4 TILT SENSOR

The ATMOS 22 is also equipped with a tilt sensor similar to those found in smartphones. The primary use of the tilt sensor data will be to ensure the ATMOS 22 remains level at all times. Regularly check X and Y tilt data to ensure the ATMOS 22 is level; if it has tilted, return to the site and level again. Although this sensor may also be used to level the instrument during installation, it is much easier to use the small bubble level on the bottom of the anemometer plate.

NOTE: Tilt data will not be collected by legacy Em50 series data loggers.

### 3.5 WIND SPEED AND DIRECTION THEORY

The theory behind the anemometer comes from Campbell and Unsworth (1979). The speed  $c$  (m/s) of sound in still air depends on air temperature  $T$  (K), vapor pressure  $e$  (kPa), and atmospheric pressure,  $p$  (kPa), as shown in Equation 1.

$$c = 20.067 \sqrt{T \left( 1 + \frac{0.32e}{p} \right)} \quad \text{Equation 1}$$

For a given sound path length,  $d$  (m), the number of wavelengths,  $n$ , in still air is determined with Equation 2.

$$n = \frac{vd}{c} \quad \text{Equation 2}$$

Here  $v$  is the frequency of the sound (Hz). When the air is moving, the speed of sound is the sum of the wind speed and the speed of sound in still air. The anemometer transmits a sound pulse in a forward direction, then a similar pulse in the reverse direction. The difference in  $n$  between the two points is computed. If the vector magnitude of the wind in the direction of the sound is  $u$  (m/s), then

$$n - \Delta n_+ = \frac{vd}{c + u} \quad \text{Equation 3}$$

$$n - \Delta n_- = \frac{vd}{c - u} \quad \text{Equation 4}$$

for sound traveling with and against the wind. Subtracting the result of Equation 3 from the results of Equation 4 creates Equation 5.

$$\Delta n = \Delta n_- - \Delta n_+ = \frac{2vdu}{c^2 - u^2} \quad \text{Equation 5}$$

Even at the maximum wind speeds for the anemometer,  $u^2$  is only about 1% of  $c^2$ , so the equation can be simplified as shown in Equation 6.

$$x \cong \frac{c^2}{2vd} \Delta n \quad \text{Equation 6}$$

This is the basic equation for the anemometer. Delta ( $\Delta$ )  $n$  is proportional to the phase difference between the forward and reverse sound pulses. The sound comes from a 40 kHz ultrasonic transducer in the head of the anemometer. A sound pulse is transmitted diagonally across the anemometer, bouncing off a sintered glass disk in the center. The sound pulse is then received by another transducer in the anemometer head that is opposite the first. Once the sound pulse is received, the receiver becomes the transmitter and the process is repeated. Two more sensors, mounted at 90 degrees from the first two, give the other horizontal component of the wind. The sound travels a total distance of about 72 mm from transmitter to receiver, but  $d$  in the equations is just the horizontal distance, which is 40 mm.

If  $u$  is the magnitude of the wind vector in the east–west direction (east +) and  $v$  is the magnitude in the north–south direction (north +), then wind speed is computed with Equation 7.