Sonic Anemometers

by Steven Curtis

Introduction

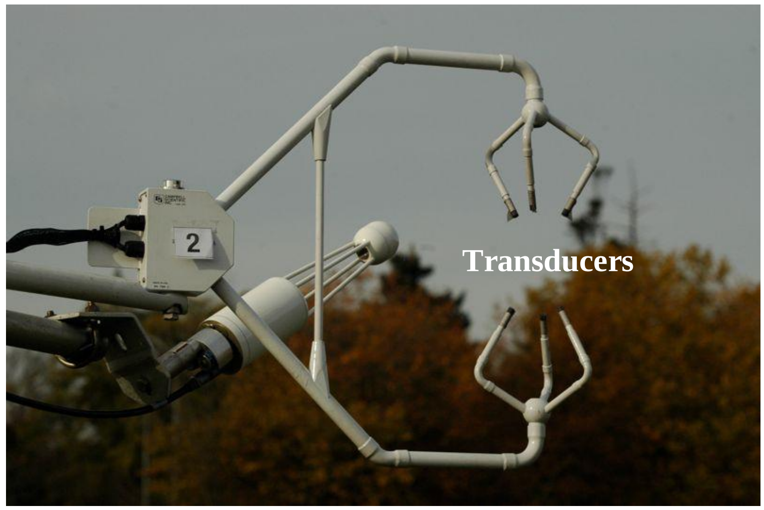

Figure 1: Sonic anemometer in the field.
http://www.geog.ubc.ca/courses/geob300/images/field-visit-2/Pages/5.html

Instruments used to measure wind speed have been around since the 1400's (University of North Dakota, 2008). These tools, coined anemometers, vary in complexity and in the data they can measure. Anemometers, derived from the Greek word *anemos* meaning wind, have progressed significantly in the last several years (University of North Dakota, 2008). Most recently, the sonic anemometer was invented in the 1970's and stands as one of the most influential meteorological tools. Figure 1 shows a sonic anemometer deployed in a clearing where measurements are being recorded. This instrument utilizes sonic technology to measure wind velocity. Sonic pulses are emitted and received by a series of transducers that operate at a high frequency. The speed of the wind can be determined by measuring the speed of the sonic pulses between the transducers. The transducers operate continuously and measure wind velocity accurately. Because of this, these measurements are often utilized in computing turbulence within the lower atmosphere.

Definition

Within the field of meteorology, wind speed is an important quantity to measure. Whether wind speed is being used to predict temperatures or the spread of pollutants, it is essential in the role of the meteorologist. The sonic anemometer is the leading tool within the field of atmospheric science at measuring wind speed and direction. Different from other anemometers that measure wind speed, the sonic anemometer measures wind velocity, a vector quantity consisting of wind speed and direction.

Design and Location

The design features and location of the sonic anemometer are crucial in accurate and useful wind measurements. The design of a sonic anemometer is depicted in Figure 2. Sonic anemometers are often designed to be aerodynamic. This helps to limit the effects the instrument has on altering the measured wind velocity. Moreover, the anemometer is white to reduce the absorption of energy. If energy were absorbed, the temperature of the air surrounding the anemometer could fluctuate influencing the accuracy of the measurements.

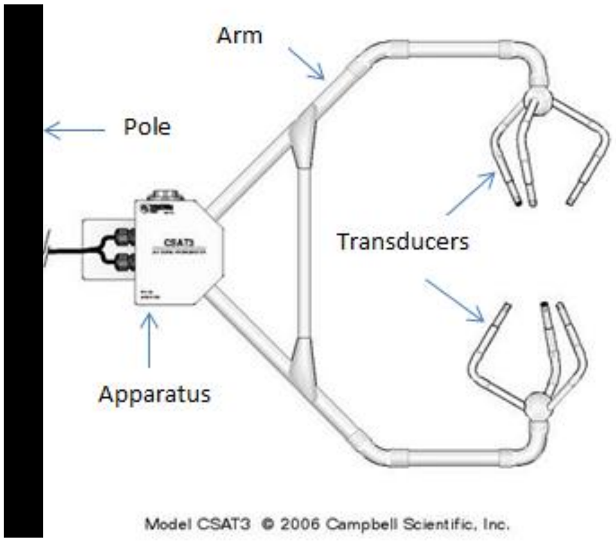

Figure 2: Labeled sonic anemometer diagram. Adapted from: http://atmoswiki.aero.und.edu/atmos/535/projects/csat3_3-d_sonic_anemometer

As seen in the figure, the sonic anemometer consists of an apparatus that contains two protruding arms. The arms are usually arranged so that they are parallel. Each arm has three transducers which correspond to a matching sensor on the other arm, making a pair of transducers. Each transducer is designed to both emit and detect the sonic pulses. The sonic anemometer is typically a part of a larger measuring station consisting of other meteorological instruments. The station houses the software used to compute the wind velocity and measures air density and temperature.

The public think of wind measurements as those reported on the nightly news. In those instances, sonic anemometers are used individually for daily observations of wind speed. However, more commonly, multiple sonic anemometers are deployed in the field to gather measurements used for research. As seen in Figure 3, these instruments are arranged on a vertical pole which varies in length approaching twenty-five meters. The poles allow for wind velocity comparisons in the vertical and horizontal. Locations of the measuring stations depend on the research: pollutant, heat, and moisture transport; height of the convective boundary layer (base cloud layer); effects of tree height on surface wind speed; among others. The measuring stations are immersed in the research area, both rural and urban.

Sonic Technology and Measurements

Sonic anemometers utilize the science surrounding sound waves. Sound waves are dependent on the properties of the medium in which they move, in this instance, air. Given the temperature and density, the speed of sound in a vacuum can be calculated. The sonic anemometer measures the time that it takes for the sound waves to travel from one transducer to its corresponding pair. Using the elapsed time measured, the velocity of the sound waves can be computed. The measured velocity of the sound within the air is the sum of the calculated speed of sound and the velocity of the wind.

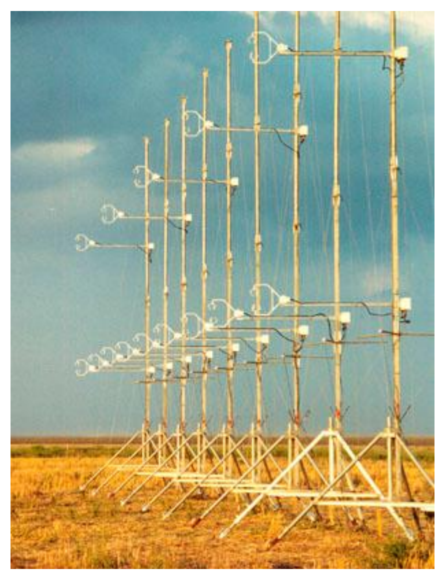

Figure 2: Sonic anemometer attached to pole. http://www.ucar.edu/communications/staffnotes/0412/awards.html

This type of anemometer is unique in that it can continuously collect data. Sonic pulses can be emitted at a frequency of 1-60 Hz. This correlates to a sonic pulse, at the very most, every second. Because the sonic anemometers can continuously gather data at high resolution, the collected data creates extensive wind velocity data sets used to conduct

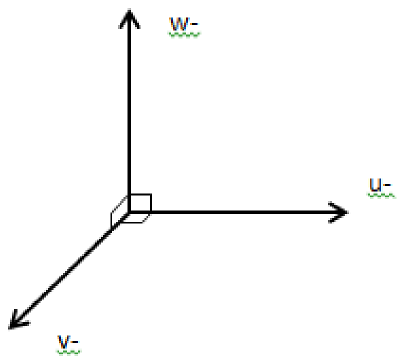

Figure 4. Components of the wind

research. Wind velocity includes the magnitude and direction of the wind. Because wind is a vector quantity, it can be broken into u-, v-, and w-components. These components correspond to vertical and horizontal direction of the wind as shown in Figure 4. These components are utilized in the study of atmospheric turbulence. In essence, turbulence is the measure of uniformity or chaotic nature of the wind components. Because sonic anemometers measure continuously, it is the best tool to measure turbulence.

Limitations

While sonic anemometers provide continuous data that is accurate, they do have their limitations. The most common problem with sonic anemometers is the influence or interference of the pole in which the anemometer is attached. In order to ensure stability, the pole design may interfere with the wind velocity surrounding the anemometer. The pole deflects or changes the course of the wind measured by the sonic anemometer. Depending on the speed and direction of the wind, the impacts on the measurements can be significant. This must be reflected in the research when using the data collected.

As discussed previously, the properties of the air impact the calculated speed of sound and consequently the measured wind velocity. In instances when the air temperature and density change quickly, measurements can be effected. This situation occurs before or after storms, during strong wind events, and possibly during uneven daytime heating of the atmosphere. Moreover, precipitation, such as rain or snow, directly impacts the measurements by deflecting the sound waves. The deflected waves never reach the transducers and wind velocity is not measured. Dust or fog has also shown to have impacted the accuracy of the measurements.

Conclusion

Anemometers have evolved over time. While limitations exist with the sonic anemometer, currently, it serves as the most useful measure of wind velocity. This instrument continuously measures wind velocity and its components. Sonic anemometers have a wide variety of uses from operational forecasting to atmospheric research. Due to the high resolution of the data collected, the instrument enables meteorologists to accurately report current wind velocity and accurately calculate atmospheric turbulence.

The data collected from the sonic anemometer has many implications within the field. Most importantly is advection. This phenomenon is the transport of a quantity due to wind speed and direction. Wind can advect or transport temperature, moisture, forest fire smoke, and harmful gaseous particles such as ozone, sulfur dioxide, nitric oxide, and even nuclear radiation. Moreover, sonic anemometer data can be used to determine the turbulence of the atmosphere. This affects the development of the cloud base or even severe thunderstorms. Without sonic anemometers, much of the research within the field of atmospheric science would not be possible.

Works Cited

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