Weather Observation and Analysis

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Course Notes

Chapter 3. SPACE, TIME, AND MOTION

3.1 Wind Observations

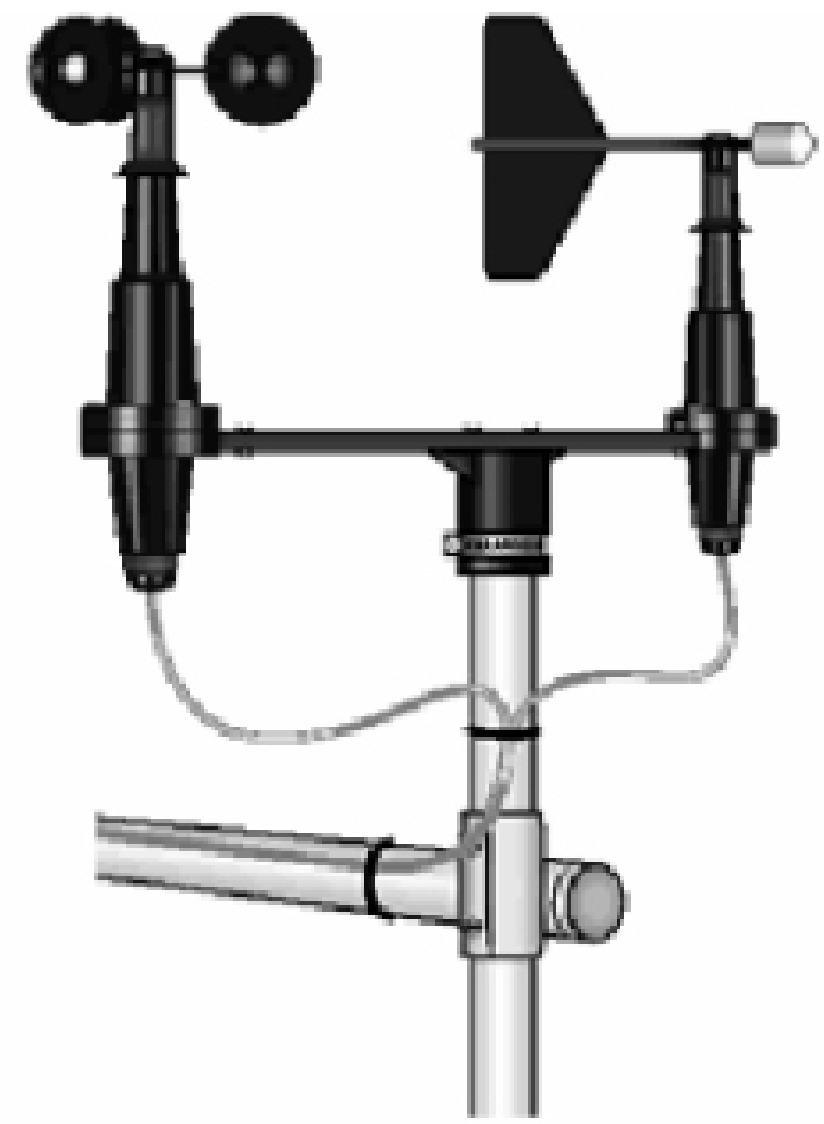
We can divide weather elements into scalars and vectors. Anything that can be represented as a single value is a scalar. Almost all observed atmospheric quantities are scalars. Temperature, dewpoint, pressure, rainfall, infrared radiation, concentration ... all of these are things whose value is specified by a single number. The one important exception to the ubiquity of scalars is wind.

Wind, like all vectors, has a magnitude and a direction. The wind is defined as the motion of the air at a particular location, averaged over some period such as two or ten minutes. According to normal convention, the wind is a two-dimensional vector. Strictly speaking, air moves in three dimensions (east-west, north-south, and up-down), and sometimes the velocity vector is taken to be the full three-dimensional wind, but it is more common in normal use to work with the vector horizontal wind and treat the vertical component of air motion as a separate scalar. Thus, an air parcel might be said to have a wind vector of 16 m/s from 130 degrees and also be ascending at 2.4 cm/s. Remember that wind directions are expressed as the direction the wind is coming from, not the direction it is going toward.

As with all vectors, the wind can be described in terms of its components as well as a speed and direction. There's no law that requires it, but you are probably accustomed to the three cartesian coordinates being designated as x, y, and z. By similar inviolate convention, the three components of air motion (toward the x, y, and z directions respectively) are represented as u, v, and w. When the air motion was described as 16 m/s from 130 degrees and ascending at 2.4 cm/s, that 2.4 cm/s was the w

component of the air velocity, the component of motion in the positive z direction. You could compute the u and v components of motion from the horizontal speed and direction using trigonometry. That technique will be reviewed in Chapter 12.

Whether you choose to express the horizontal wind as separate components or as a speed and direction, you need to use two numbers. Thus, as you might imagine, the measurement of the wind generally requires two instruments. At simple weather stations, these instruments are an anemometer (for horizontal wind speed) and a wind vane (for horizontal wind direction). The most common anemometer is a cup anemometer. The cup shape ensures a particular direction of spin. The speed of rotation of the cups is recorded and converted to a wind speed using a previous calibration. The wind vane is simpler, a generally flat plane that orients itself with the wind.



A wind vane and cup anemometer, manufactured by R. M. Young. Image (c) 2000, 2005 Campbell Scientific, Inc.

Sometimes the two wind instruments are combined onto one, with the wind speed instrument mounted on the leading edge of the wind vane. Since the wind vane points toward the wind, the anemometer can be a propeller. Propellers generally respond faster to changes in wind speed than cups because their moment arm is smaller.

A propeller anemometer and wind vane, manufactured by R. M. Young. Image (c) 2000, 2005 CAmpbell Scientific, Inc.

With two propellers mounted at right angles, you don't need a wind vane at all. When one propeller is pointed toward the west and the other pointed toward the south, the propellers directly measure the two components of the horizontal wind. A little trigonometry then gives you the wind speed and direction.

Even propellers take time to spin up. What if you want to measure the wind almost instantaneously? The most common instrument for that task is a sonic anemometer. A sonic anemometer measures each wind component individually by measuring the time required for a sound pulse emitted by one transducer to be received by another transducer. Sound waves are affected by wind just like aircraft are: with a tailwind, the sound waves move faster; with a headwind, they move slower.

You may know that the speed of sound is also affected by temperature. To eliminate any complicating effects, the measurement is repeated with the transmitter now the receiver. The difference in transit times is proportional to the wind speed. With transmitter/receiver pairs oriented along three axes, the three components of the air velocity can be measured. This type of instrument can be more robust than normal anemometers because there are no moving parts.