Mustansiriyah Uni.
College of science
Atmospheric Science Dept.

الجامعة المستنصرية
كلية العلوم
قسم علوم الجو

المرحلة ألثانية

Meteorological Instrumentation and Observations

Lecture Title عنوان المحاضرة

Wind Speed and Direction

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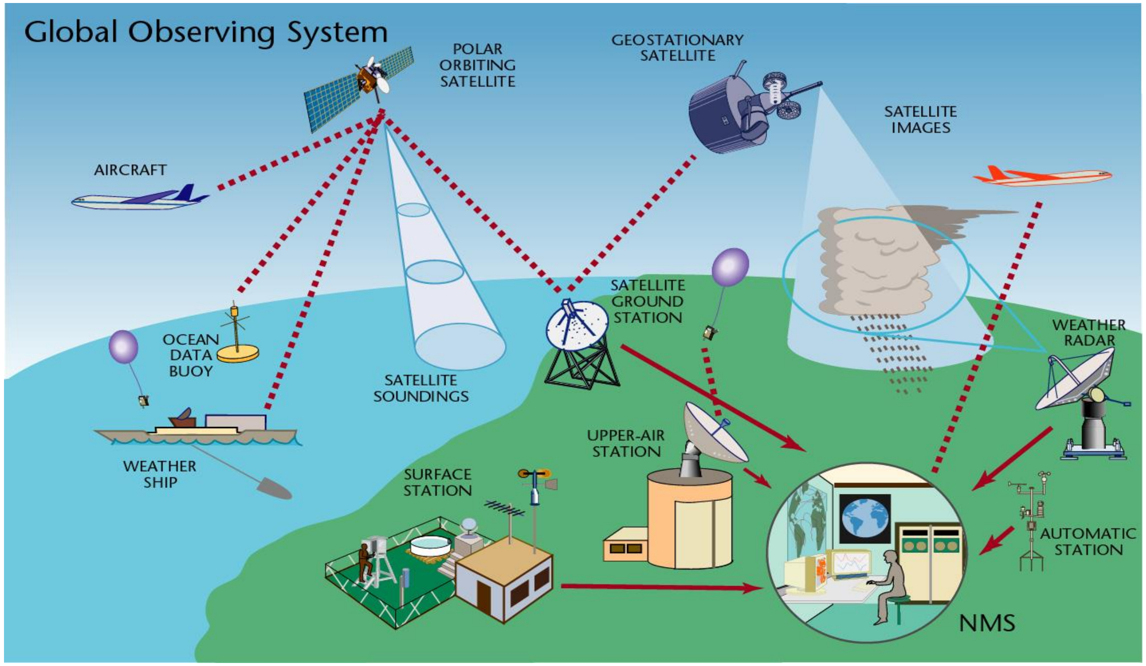
The Course of
Meteorological Instrumentation and Observations



MUSTANSIRIYAH UNIVERSITY
COLLEGE OF SCIENCES
ATMOSPHERIC SCIENCES DEPARTMENT

2019-2020

Dr. Ali Alhafiz

SECOND STAGE

Wind Speed and Direction

Although airflow in the atmosphere is a three-dimensional velocity field, it is the **horizontal component of its motion** which is commonly measured, because the vertical component is generally much smaller.

Measuring the horizontal air velocity determines the **wind vector V** = (u, v), where u is the west to-east (*zonal*) component, and v the south-to-north (*meridional*) component.

Often only the **magnitude of the vector** (i.e. the wind speed, which is usually given the symbol U) is measured, with the wind direction measured entirely independently.

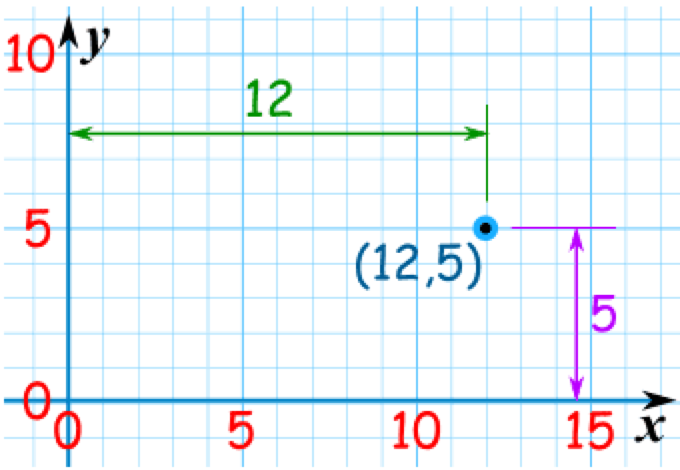
An instrument for measuring the wind speed is known as ***anemometer***; the mechanical device turned by the wind to indicate the direction from which the wind is blowing is a ***wind vane***.

Properties used to determine wind speed include the flow's kinetic energy (dynamic) (cup and propeller anemometers), cooling (hot wire or film anemometer) and the effective speed of sound in a moving reference frame (sonic anemometer).

FYI

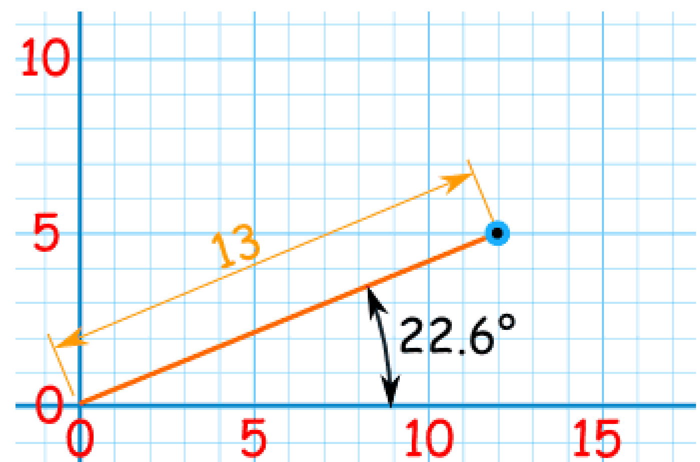
Cartesian Coordinates

Using Cartesian Coordinates we mark a point by **how far long** and **how far up** it is:



Polar Coordinates

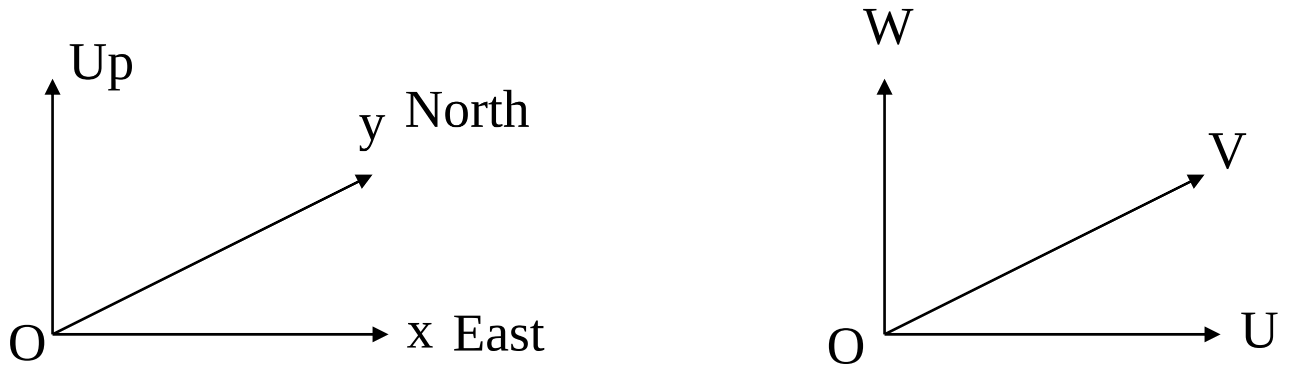
Using Polar Coordinates we mark a point by **how far away**, and **what angle** it is:



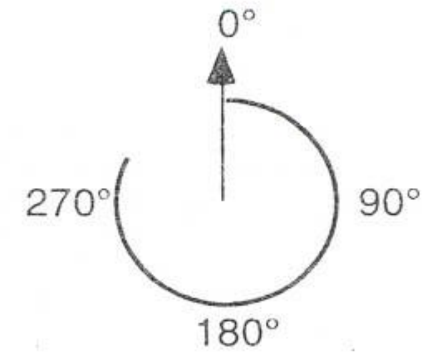
Wind Measurements

Wind measurements are usually taken in the *polar coordinate*, in which winds are written as two components: wind speed and direction.

Local right-hand Cartesian coordinate



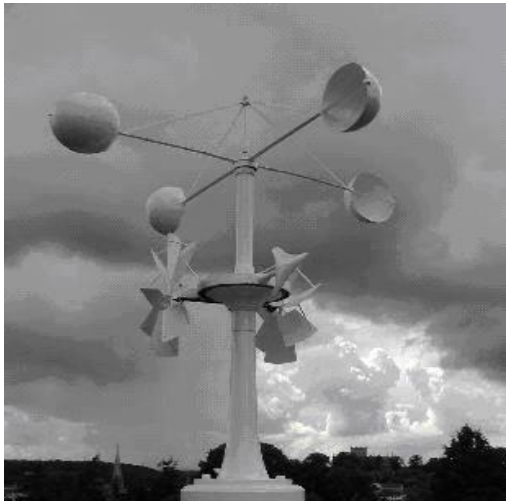
Polar coordinate



Meteorological

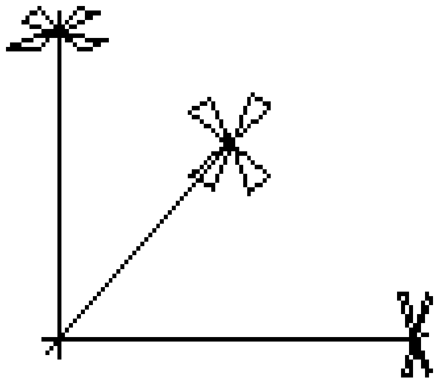
1. **Dynamic force anemometers:** they consist of cup anemometers, vane windmill, and gill-type anemometers .

- The rotation rate is proportional to wind speed, which sometimes drives an electrical generator that gives voltage output which is proportional to the wind speed.
- The inertia of the sensor determines the threshold. Thus, the smaller and lighter of the sensor, the more sensitive it is.



Cup anemometer

Vane windmill



Gill-type anemometer

Cup anemometer

A typical cup anemometer has three conical or hemispherical collecting cups mounted at equal distances from a vertical shaft by equally spaced horizontal supporting arms. The vertical shaft rotates on bearings arranged to cause as little mechanical loading as possible. The asymmetry of the cup arrangement ensures that the anemometer always rotates the same way irrespective of the direction of the incoming wind. The response characteristic of a cup anemometer is close to linear, and can be described by $\omega = k\,(U - U_0)$,

where ω is the angular rotation speed, U is the wind speed, U_0 is the starting speed for the anemometer and k a calibration constant. Typically, U_0 is about 2 m s^{-1} for large-cup anemometers used in a climatological station, but may be only 0.5 m s^{-1} for a light anemometer with good bearings as used in micrometeorology.

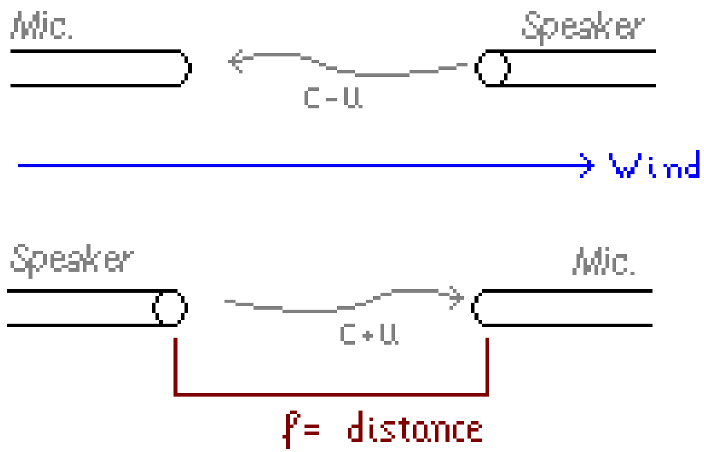
The output signal from a cup anemometer may be a voltage proportional to rotation speed (e.g. from a DC generator) or a series of electrical pulses generated by an optical or magnetic switch on the rotating shaft.

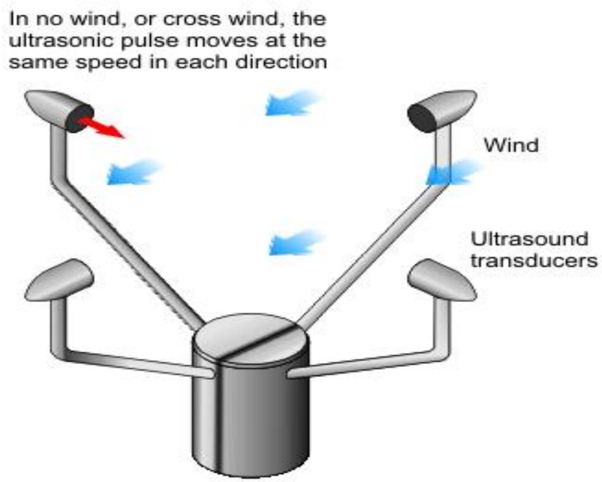
Anemometer factor :is the actual relationship between the speed of the wind and the speed of the cups. It depends on the dimensions of the cups and arms, and the relationship may vary for different anemometers.

- To determine wind direction for cup anemometer is to add a separate of wind vane for directional readings.

Pressure pulse frequency anemometers(sonic anemometer)

It measures the variation of speed of sound with wind





The device sends a synchronized sound pulse and measures the difference in time of sound.

u is the velocity of the wind, ℓ is the distance, and c is the speed of sound.

The best way to get the wind direction is to measure the components in all three directions

2-D sonic anemometer

3-D sonic anemometer

- The spatial resolution is given by the path length between transducers, which is typically 10 to 20 cm
- Sonic anemometers can take measurements with very fine temporal resolution, 20 Hz or better, which make them well suited for turbulence measurements.

- The lack of moving parts makes them appropriate for long term use in exposed automated weather stations and weather buoys where the accuracy and reliability of traditional cup-and-vane anemometers is adversely affected by salty air or large amounts of dust.

- Their main disadvantage is the distortion of the flow itself by the structure supporting the transducers, which requires a correction based upon wind tunnel measurements to minimize the effect.

- 2-D (wind speed and wind direction) sonic anemometers are widely used in applications such as weather stations, ship navigation, wind turbines, aviation and weather buoys.

- Most sonic anemometer can also measure temperature.

Thermal anemometers (hot wire anemometers)

- It uses a very fine wire (on the order of several micrometers) electrically heated up to some temperature above the ambient.
- Air flowing past the wire has a cooling effect on the wire. As the electrical resistance of most metals is dependent upon the temperature of the metal (tungsten is a popular choice for hot-wires), a relationship can be obtained between the resistance of the wire and the flow velocity.

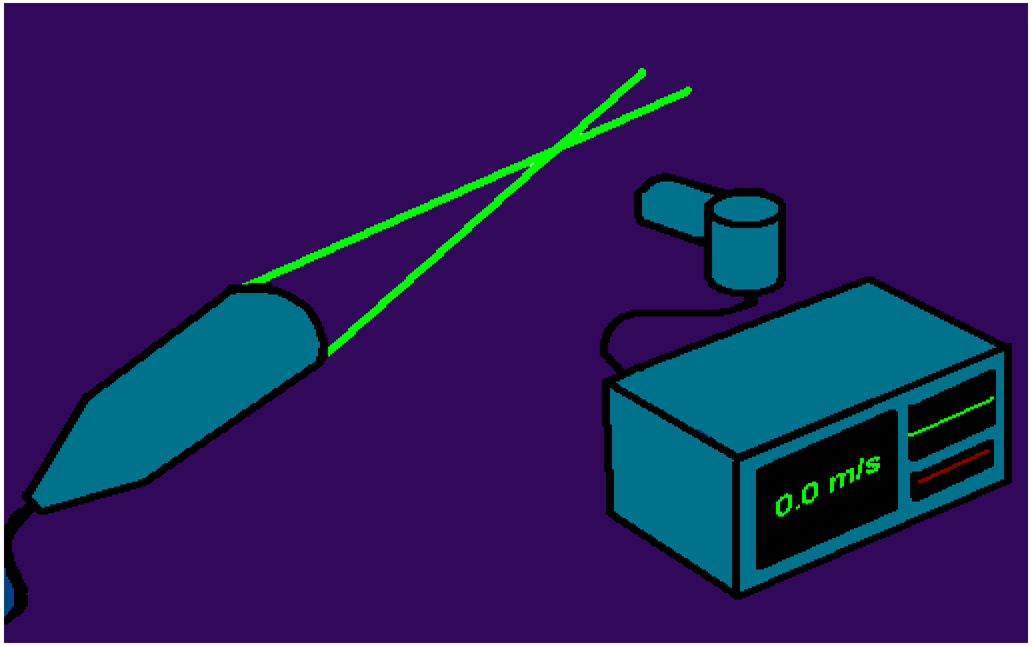
Hot-wire devices can be classified as

1. CCA (Constant-Current Anemometer)
2. CVA (Constant-Voltage Anemometer)
3. CTA (Constant-Temperature Anemometer)

- The voltage output from these anemometers is thus the result of some sort of circuit within the device trying to maintain the specific variable constant (current, voltage or temperature)
- For example, in CTA mode, the current I through the sensor is related to the wind speed by King's law

Laser Doppler anemometers

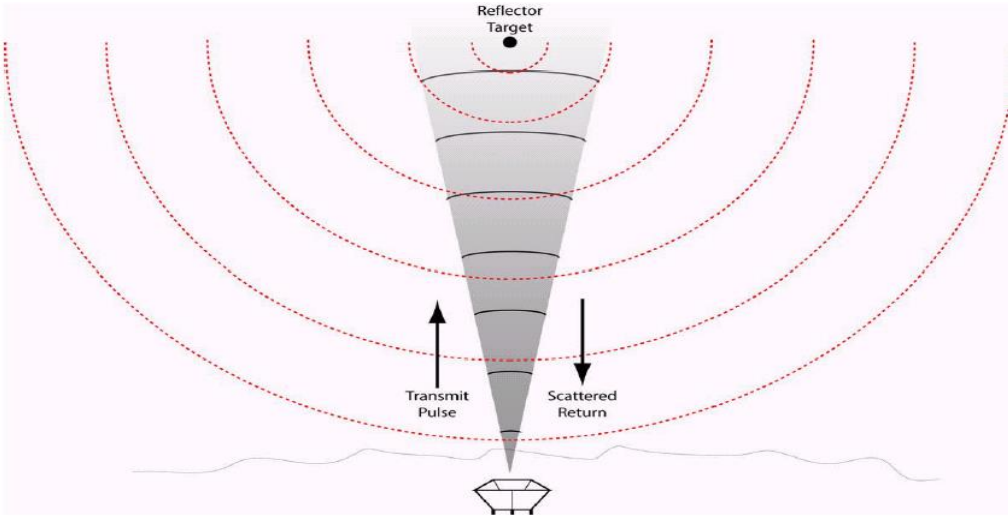
- Laser Doppler anemometers use a beam of light from a laser.
- Particulates flowing along with air molecules near where the beam exits reflect, or backscatter, the light back into a detector, where it is measured relative to the original laser beam.



- When the particles are in great motion, they produce a ***Doppler shift*** for measuring wind speed in the laser light, which is used to calculate the speed of the particles, and therefore the air around the anemometer.

Wind profilers

- A wind profiler is a type of sensitive Doppler radar that uses electromagnetic waves or sound waves (SODAR) to detect the wind speed and direction at various elevations above the ground, up to the troposphere (i.e., between 8 and 17 km above mean sea level).
- A wind profiler is designed to point (nearly) vertically and to respond to fluctuations of the refractive index of the (clear) air.
- The fluctuations of the refractive index are due to turbulence.
- They are so sensitive that they can translate the backscattered energy from these eddies into a vertical picture of wind speed and direction in a column of air.
- Wind Profilers detect minute fluctuations in atmospheric density, caused by the turbulent mixing of volumes of air with slightly different temperature and moisture content.



Typical frequencies used in wind profiling

45-65 MHz

404-482 MHz

915-924 MHz

1280-1357.5 MHz

The 915 MHz (33 cm, UHF) profiler measures the wind at low levels, typically up to 1-3 km above ground level, depending on atmospheric conditions, especially humidity. The top of the atmospheric boundary layer marked by the entrainment zone is very visible because the large humidity and temperature gradient there cause a large change in index of refraction. The 915 MHz profiler has fairly small antennas (at most 2x2 or 3x3 m), making it transportable and less expensive.