INSTRUMENTS GENERAL

Overview

Accurate and reliable meteorological instruments and systems are key to the success of the various meteorological observing programs. Instruments range in sophistication from a basic metre stick for snow depth measurements to the Canadian designed Brewer spectrophotometer for ozone measurements. The climatological and aviation programs in particular require data of high caliber capable of being useful in detecting climatological change and in contributing to the safety of air operations. When data serves more than one purpose, whenever possible, the accuracy requirements for the instruments are set high enough to meet the most stringent needs. Performance specifications such as range, accuracy, error and response time need to be established for the sensors before procurement and deployment. Instrument calibration in relation to a bench standard is a requirement for many operational sensors as is a program to verify field performance against a travelling standard in ensuring that recorded measurements continue to reflect the intrinsic performance capability of each sensor.

Proper siting is also critical to sensor performance. Things like trees and buildings can affect wind measurements and the height of a thermometer or anemometer above the ground can affect temperature and wind readings. Even the actual procedure used to take a measurement can affect the reading so detailed observing procedures need to be fully documented and adhered to in an effort to ensure consistency. Changes to a site over time need to be minimized; the installation of a back-yard patio might affect temperature readings and urban growth can turn a rural site into an urban one.

All aspects of the observing systems including instrument and site characteristics, any algorithms used to process the data and general operating procedures need to be fully documented since all could have an influence on the data history. In some cases statistical techniques can be applied to well documented changes in facilitating a comparison of the data sets obtained under differing regimes. This documentation or metadata should be available to users as part of the overall data management process since it is important for the best use and interpretation of data and data products.

Surface Observing Instruments

At any given time a variety of instruments can be in operational use with respect to the same meteorological parameter. In addition instruments have changed over the years with the result that the national climate archive includes information measured by a wide variety of sensors. For practical considerations only a short description of some of the key instruments in current use will be included in this topic. Some sensors are common to both staffed and AWOS sites, as is the goal to have the instruments sited in open terrain away from obstacles, as illustrated in the AWOS installation shown below.

Temperature:

Mercury thermometers have long been the mainstay of staffed and volunteer observing sites for the measurement of air temperature. The mercury thermometer is very accurate and capable of providing data suitable for tracking any small change in climate. Alcohol thermometers are used at very cold temperatures when mercury is susceptible to freezing. "Maximum" and "minimum" thermometers have traps placed in their capillary tubes allowing the mercury to expand or contract with increasing/decreasing temperature but unable to flow back when the temperature drops/rises (unless shaken vigorously). All thermometers are housed in a white painted louvered enclosure called a Stevenson Screen.

At AWOS sites air temperature is measured using a "thermistor" placed within a Stevenson Screen. The sensor is placed in an electrical circuit as a resistor. The resistance changes with temperature and the sensor is calibrated to report temperature to 0.1 C.

Humidity:

Staffed sites make use of a wet and dry bulb psychrometer with appropriate tables to determine dew point and relative humidity. At some locations, including AWOS, a DewCel mounted in a Stevenson Screen is used to measure humidity. It consists of a chemically treated temperature probe over which is wound a pair of bare wires. The chemical absorbs moisture from the air and causes a temperature change proportional to water vapour pressure, which is then converted to a dew point temperature.

Atmospheric Pressure:

A mercury barometer remains in operational use at staffed observing sites.
Atmospheric pressure is balanced against the weight of a column of mercury (connected to a small cistern at the base) of approximately 75 cm (30 inches) in length. The height of the column at the observing station is read on a scale graduated in hectopascals (hPa). A number of corrections are applied to the observed value in determining the true "station pressure"; these include an individual barometer calibration factor and a correction for temperature since it also affects the height of the column (i.e. causes an expansion or contraction of the mercury). Once the station pressure is determined the Mean Sea Level (MSL) pressure and altimeter setting are calculated using tables or computer software. A barograph consisting of an evacuated chamber connected to a rotating drum with a chart record is used to determine the "pressure tendency" which refers to both the amount of pressure change over a three-hour period and the exact nature of the change (steady rise; irregular rise etc.) Electronic barometers are also available at some sites.

The AWOS pressure sensor consists of two electrodes configured as a capacitor inside a vacuum chamber. Pressure changes cause a deformation of the chamber and a change in the capacitance, which is converted into a station pressure reading in hPa. Code conversion software calculates MSL pressure and altimeter setting.

Wind:

Several instruments are in operational use for the purpose of measuring wind. The U2A System consists of separate speed and direction measuring systems. Speed is determined from the output voltage of a DC current generator driven by the wind movement of an anemometer cup wheel. Direction is determined from the electrical output of a synchro-positional motor controlled by a wind vane; the system requires an external power supply. Speed and direction readings are transmitted via cable to dial indicators and sometimes also to a chart recorder. The 78D Anemometer System has some components in common with the U2A. The system uses low DC power optoelectronic transducers connected to an AC powered display unit.

AWOS wind measurements are made with 78D systems. The system stores data used in determining outputs of two and ten minute means, 10-minute peak gust and 60 minute peak speed and direction.

Precipitation Typing and Measurement

At staffed sites the occurrence, type, intensity and amount of precipitation is determined by direct observation and the use of standard cylindrical non recording gauges and Fisher-Porter (FP) weighing gauges for amounts; a Tipping Bucket Rain Gauge connected to a chart recorder is used to measure rainfall rates. AWOS uses a modified FP weighing gauge to measure total precipitation; snow data is reported as water equivalent but the collection efficiency of snow is problematic, especially in windy conditions. AWOS uses a sophisticated Precipitation Occurrence Sensor System (POSS) consisting of a small Doppler radar pointing upwards to detect reflections from falling precipitation in the few centimetres above the instrument. POSS uses the Doppler frequency shift to determine the speed of the falling precipitation, which in combination with dew point temperature readings is used to identify the type of precipitation. A multi-parameter processing algorithm integrates additional data from a separate ice accretion sensor in identifying the occurrence of freezing rain and freezing drizzle. Birds, insects and Radio Frequency (RF) interference cause some false reports of precipitation but most of these are now filtered out.

Cloud Height

The heights of clouds above ground are important to aviation. Both staffed and AWOS sites use a Laser Ceilometer in determining the height of the base of the cloud. A gallium arsenide laser emits a pulse vertically and any cloud will reflect a signal back to the instrument where it is compared with a reference signal. In an AWOS installation the instrument keeps sufficient data in memory to be able to estimate the amount of cloud averaged over an hour. The instrument is effective to 10 000 feet; other limitations relate to false cloud reports during ice crystals and a tendency to estimate cloud bases as being lower than they are.

At night human observers can also make use of a light emitting rotating Ceiling Projector Beam and/or a Ceilometer Recorder Record as aids in estimating both the amount and height of lower cloud bases. A small searchlight projects a narrow beam upwards and heights are determined by means of an alidade and amounts are estimated by the trace on the recorder record. During daylight hours, balloons of known ascent rates are also used to estimate the height of lower cloud bases.

Visibility

Human observers use mostly known range markers to determine prevailing visibility for the field of view. AWOS uses a high intensity strobe transmitter and the principle of forward scatter to determine visibility along a single direction.

Bright Sunshine and Solar Radiation

These measurements are important for climatological purposes but not for aviation. Bright sunshine is measured using the weather "crystal ball". The Campbell-Stokes spherical lens concentrates the energy from the sun so that it burns a track on a chart strip. A low sun often has insufficient burning power with the result that the number of hours of "bright sunshine" is often less than the number of hours of "visible sunshine". Incoming and reflected short-wave radiation measurements are also taken by a variety of RF sensors that take readings in millivolts and convert this to watts per square metre.

Soil Temperature

A limited number of sites take soil temperature readings. The instrumentation consists of a series of glass rod thermistor elements potted in anodized aluminum tubes set at various depths and connected to a remote temperature indicator.

Evaporation

At a limited number of sites a specially designed evaporation pan is used to take measurements of evaporation totals and rates. These data are for use in the climatological program.

Upper Air and Specialized Instruments

The MSC has been in a world leader in developing ozone-measuring instruments. MSC is also currently working on a collaborative effort to develop MAESTRO for the Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation. The device will measure the chemical processes involved in ozone depletion and will be deployed aboard the Canadian satellite SCISAT-1 that is scheduled for launch in mid 2002. MSC also participates in MANTRA (Middle Atmosphere Nitrogen Trend Assessment) balloon flights to measure ozone, nitrogen compounds and stratospheric aerosols.

Review Questions

1. True or false: proper siting is critical to the performance of meteorological sensors. ________________________. *ANS: True*
2. The primary instrument used to measure atmospheric pressure at staffed stations is the____________________________. *ANS: Barometer*
3. The "POSS" is the component of AWOS used to________________________ __________________________________. *ANS: Detect precipitation electronically*
4. True or False. The U2A System is an externally powered wind system that measures only the wind speed. _________________. *ANS: False. It also measures wind direction.*
5. The number of hours of "bright sunshine" as measured by a Campbell-Stokes Sunshine Recorder is almost always __________________ the number of hours of "visible" sunshine as reported by a human observer. *ANS: "…less than…"*