Using 3D-Printers and Low-Cost Microcontroller Boards to Build Open-Source Environmental Instrumentation
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System Design

The objective of this project was to design, prototype, and test a research-grade weather station that is based on open-source hardware/software and off-the-shelf components. Some parts were fabricated using a 3D printer. The system measures atmospheric variables: air temperature, humidity, global radiation, wind speed, wind direction, precipitation. The Arduino-based datalogger collects averages and other statistics after stores time-stamped data to an SD card.

Temperature and RH

Two devices that showed promise for measuring temperature and humidity were: 1) the SHT15 (Sensirion Electronic), and 2) the Vaisala HMP45C sensor on a station operated by the Department of Atmospheric Science, Colorado State University. Naturally vented shields were used on both stations.

Solar Radiation

A "preature" fan-ventilated shield for improved temperature measurements was developed for the SHT15 sensor. It has a 30cm fan with bidirectional airflow and a temperature sensor mounted near 4 m. The shield of the SHT15 sensor was then tested to reduce radiation errors. This shield will be field tested in the summer of 2014.

Software

-立ち上げ power is provided by a 1.8W solar panel, charge controller, and controller.
- 12V, 7AH battery and a 5V switching regulator.
- 30+ sensors every 5 seconds
- Calculates the wind vector and die-point temperature
- Stores time-stamped data to an SD card

Power


3D Printers

Lulzbot 3D, www.lulzbot.com
Airwolf 3D, www.airwolf3d.com

Temperature and RH

Comparison of the SHT15 sensor on the Arduino weather station to a nearby Vaisala HMP45C sensor on a station operated by the Department of Atmospheric Science, Colorado State University. Naturally vented shields were used on both stations.

Solar Radiation


Wind

Measuring the RPM of the Inspeed Vortex using an optical reader and an Arduino microcontroller.

Sap Flow

Heat pipes cap flow gauges have been fabricated using the 3D printer and mounted/coupled with an Arduino-based logger.

Comparison of the 3D-printed pyranometer connected to the Arduino logger to commercial instruments (model LI-200 Li-Cor, Instruments, L.C.; model Li1300, Li-Cor; Kaye Instruments, Logos, Utah) monitored by a Campbell Scientific CR800 datalogger.

Pyranometer Results

- Calibration coefficients for the PSB 1190 (photodiode with a 0.59 inch shunt resistor) and a 1.0 microfarad soft filter were 1.518 and 1.497, respectively. This translates to a 3.0% error.
- The use of a linearized 001C with an Arduino shield allowed us to calibrate the photodiode. This calibration circuit was then tested with the Arduino.
- A new shunt design was developed to handle larger current and now is used in the environmental module.
- Comparison of the SHT15 pyranometer with a commercial device (Advanced Photonics, C139, $5) showed promise for improved temperature measurements.

Field calibration of the Davis and Nova Lynx anemometers against the RM Young Wind Monitor.

Anemometer Results

- The Arduino could measure and log the RPM of the anemometers accurately provided a difference circuit was used.
- The Nova Lynx anemometers were in calibration with the RM Young and had a calibration coefficient of 0.0125 rpm per pps (pulses per second). The calibration coefficient would be fine for a hobbyist but is probably not adequate for most research.
- The wind sensor on the National Climatic Data Center was programmed into the Arduino code and validated in the lab.

Sap Flow

Early prototypes of the sap flow gauge being used in the greenhouse using geometric techniques. The total cost of building a two gauge system (sensors and logger) is about $70.

Conditioned Air Samplers for NH3

This Arduino base system is used to sample ammonia with passive samplers (bladders) near cattle feedlots. The samplers remain sealed in a tube unless wind from the direction of the source ($>15$ arc) at sufficient velocity ($>1.4$ m/s). When deployed downstream they are typically exposed about 20% of the time. Often multiple samplers are deployed in a wireless network.

Pretreatment

The Arduino loggers described here is configured to read any tipping bucket rain gauge that generates a pulse (switch closure). Sensors from Nova Lynx and Davis were successfully tested.