Low-Cost Method for Monitoring Soil Air Pressure Using Microcontroller Board

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Abstract:

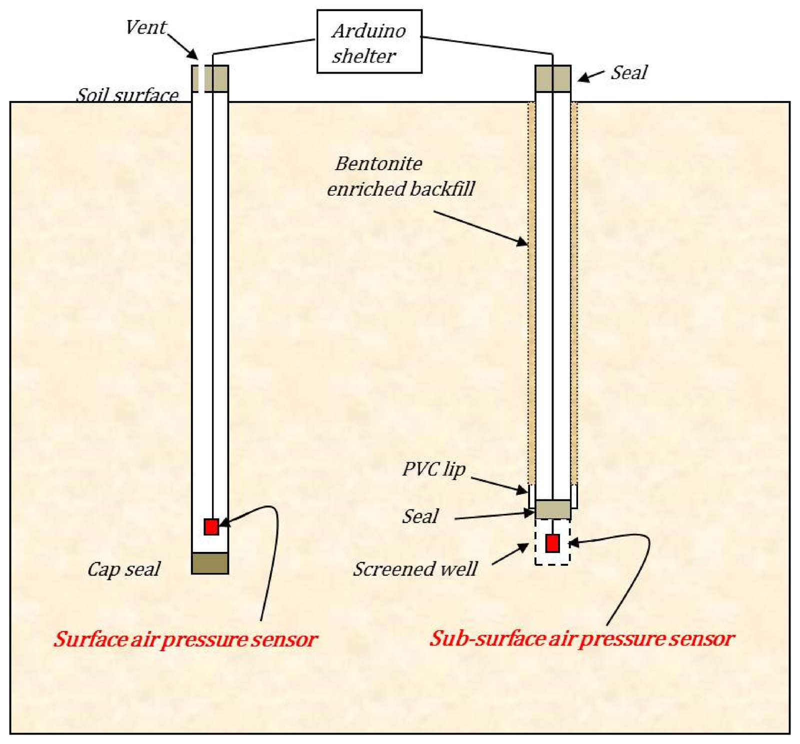
In the past it was cost prohibitive for many people to monitor and log soil air pressure changes. The objective of this project was to develop a low-cost method for monitoring soil air pressure in the field at multiple depths and locations. This project used an Arduino microcontroller, data acquisition shield (Adafruit Industries), and low cost air pressure sensors with 0.02 mbar resolution.

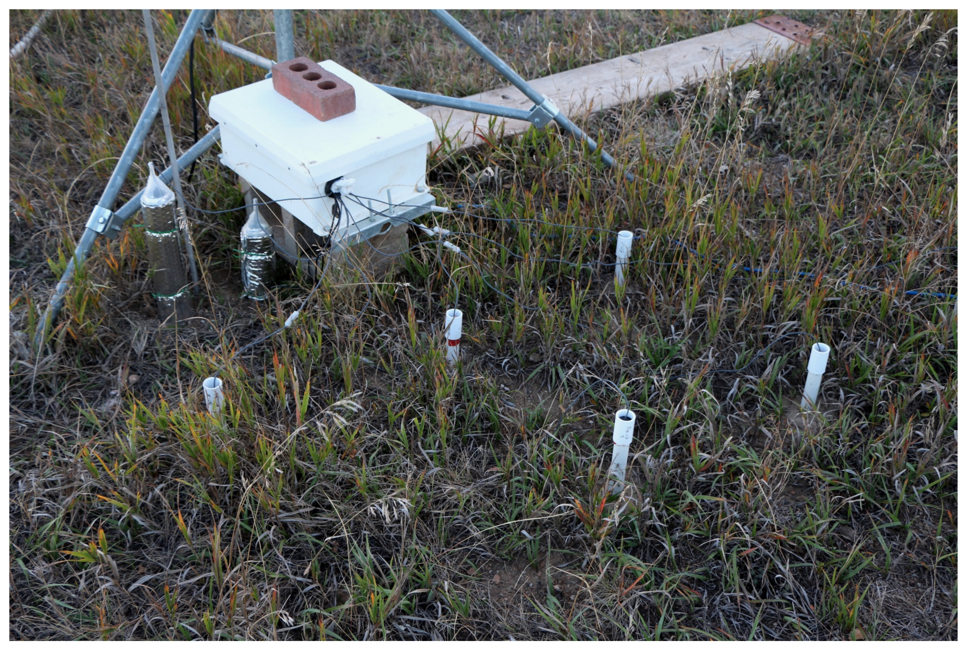
Advantages:

- Low cost data logging
- Speed of measurements (20 milliseconds)
- Resolution of sensors (0.02 mbar)

Disadvantages:

- Offset of pressure reading between sensors
- Rapid temperature changes affect pressure reading
- Long-term durability in field settings?



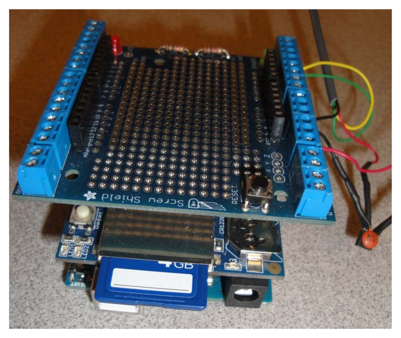


The air pressure sensor is housed in a PVC access tube. For sub-surface air pressure monitoring, the sensor is within a screened section of the PVC tube with seals at both the top of the screened section and the top of the tube. A PVC slip coupler above the screened section is a tight fit in the excavated hole for the access tube and serves as a lip to retain bentonite clay enriched (~20%) backfill that, when moistened, further seals the observation chamber from air leakage around the access tube.

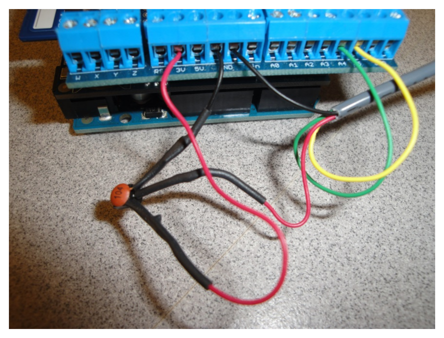
To avoid rapid temperature oscillations around a surface air pressure sensor, we hang the surface air pressure sensor in a PVC access tube sealed at the lower end but open (by a small vent protected from water entry)to the above ground atmosphere.

Tips and Tricks:

- Hang surface air pressure sensor in vented access tube to same depth as monitoring sensor.
- Insure that the wire coming up from the sensor is sealed to air flow. We noticed that there can be air flow up the insulation of the wires. This needs to be sealed prior to installation.
- Insure that the access tube is sealed to the soil after installation. We backed filled with a mixture of fine ground soil and bentonite.
- Do not have the power cords for the Arduino board in with the Arduino. There is interface with the signals and the power convertor.
- Measure the offsets of the sensors under control conditions for several days prior to installation.
- Voltage to the pressure sensors need to be regulated to 3.3 volts with an integrated circuit voltage regulator and 0.1 uF capacitor.



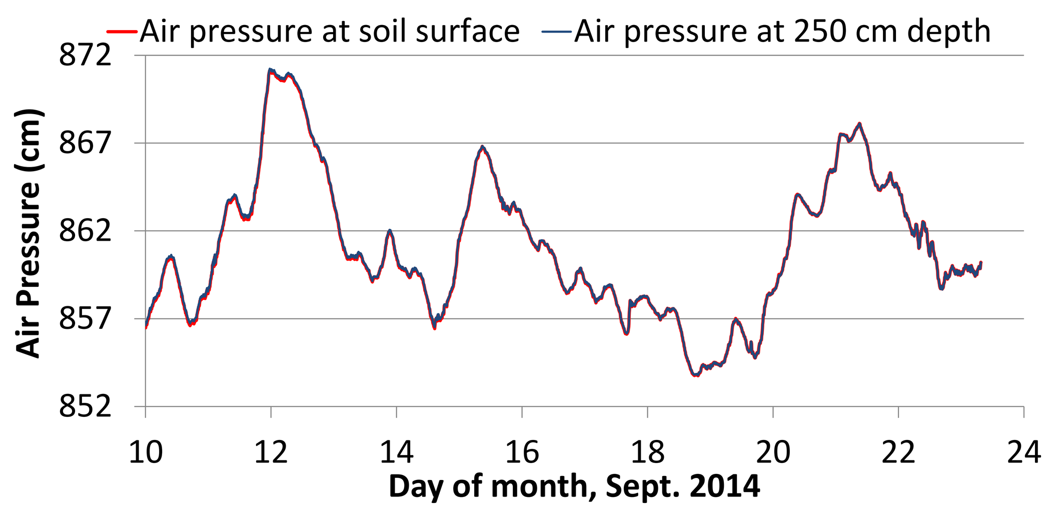
Arduino microcontroller and data logger



Voltage regulator for BMP180 sensors

Ports for connecting sensors

14 Days of monitoring data



The air pressure at the soil surface and at a depth of 250 cm over a two week time span (logged at a 2 sec interval). The soil during this time was fairly dry (about 15% water content or about 30% air filled porosity) and consequently the soil is very permeable to air. Air pressure changes at the soil surface are observed nearly simultaneously at 250cm depth. Air pressure gradients in this soil are not expected to be evident with this type of monitoring unless we have very wet soil conditions or appreciable snow cover.

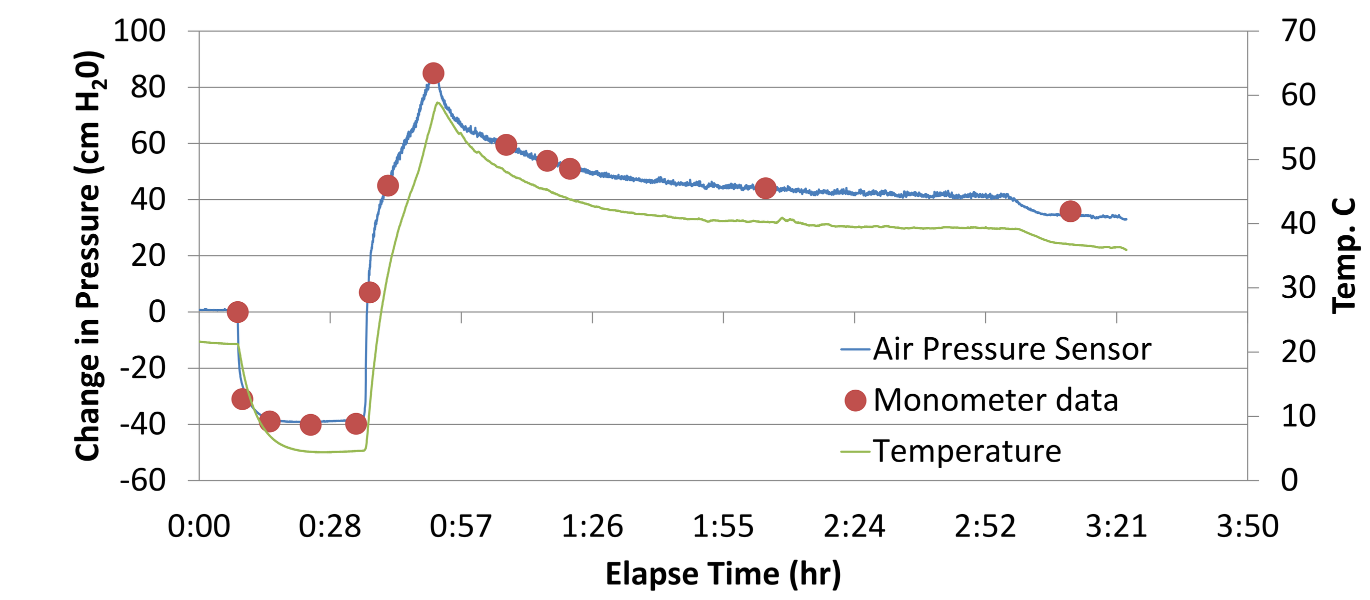
BMP 180 sensor coated with silicon

Lower end of monitoring well

Bill of materials:

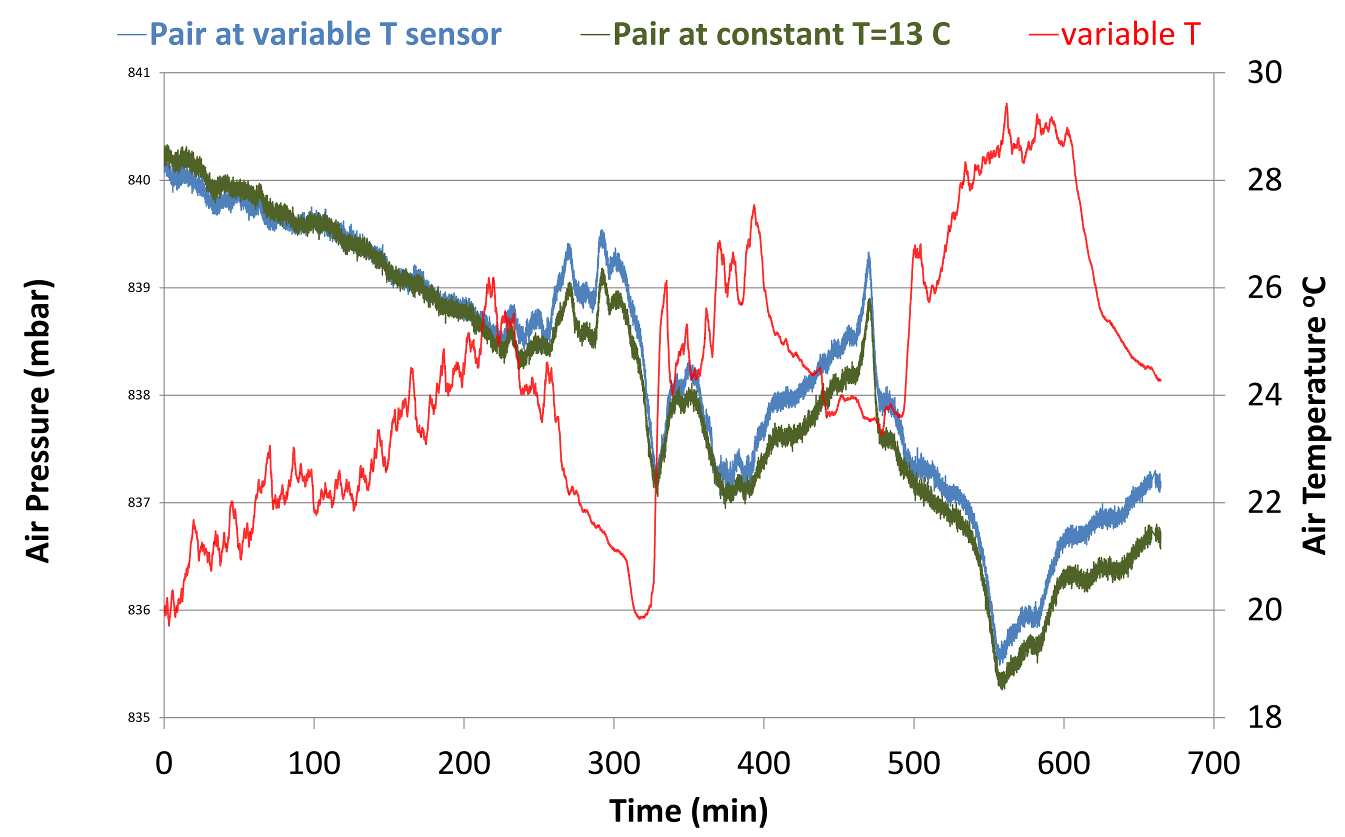
Material	Quantity	Price (Each) $	Source *
Arduino Uno	1	24.95	Adafruit.com
Data logger shield or GPS shield	1	19.95	Adafruit.com
Proto Screw header	3	16	Adafruit.com
Mux	1	6.5	dsscircuits.com
SD Card (16 gb)	1	8.95	Amazon.com
BMP180 Sensor	4	9.95	Sparkfun.com
Junction Box	1	1.84	DeepSurplus.com
4 opening Keystone Face plate	1	0.64	DeepSurplus.com
RJ 12 Female punch down connector	4	1.36	DeepSurplus.com
RJ 12 male	4	5.10	DeepSurplus.com (package of 100)
4 position connector for Mux	1	0.95	Sparkfun.com
4 position connector for 2 BMP180	2	0.95	Sparkfun.com
2 position connector for 2 BMP180	2	0.95	Sparkfun.com
4 conductor wire (telephone drop bury)	Various lengths	20	Local Hardware Store
heat shrink		6	Local Hardware Store
epoxy		4	Local Hardware Store
Silicon		10	Local Hardware Store
power supply	1	9.95	Amazon.com
LT1460 Voltage Regulator	1	3.02	DigiKey.com
0.1 uF Capacitor	1	0.30	DigiKey.com
Total		**194.49**	

*Citation of source is not intended as an endorsement.



Comparison of temperature variation on air pressure sensor versus monometer data –

A BMP180 sensor was placed in a sealed Erlenmeyer flask to measure air pressure (blue line) and temperature (green line) through a sequence of imposed variations. A monometer was also connected to the Erlenmeyer flask to provide independent measurement of air pressure changes (red markers). The flask was allowed to equilibrate at room temperature followed by placement in an ice bath and subsequently in warm water. The plot above shows the change in the reading of the BMP180 sensor in the flask relative to the original equilibrium value (blue line). It was assumed that the system was closed to air flow and that the background air pressure was not changing during the experiment. The results illustrate that the BMP180 sensor is able to measure the rapid changes in pressure due to temperature change. It also shows that the sensors are as accurate as the monometer for this experiment.



Effect of temperature variation on the apparent air pressure-

There are inherent (albeit small) differences (δ) between the BMP180 sensors in air pressure readings. In order to use the sensors at different soil depths to monitor air pressure gradients it is required that δ is known and remains a constant. Here is an example of two sensors at the same actual air pressure but different temperatures regimes (one at constant T and the other at variable T). The δ for these sensors is 0.18 mbar on average but varies between -0.66 mbar to 0.35 mbar, with the largest deviations occurring when the temperature is changing rapidly. This suggests that sensors at the soil surface subject to chaotic air temperature changes will, when compared to subsoil sensors at stable temperatures, give fictitious air pressure gradients and lead to false estimates of the both the magnitude and direction soil air advection.