Instrumentation for measurement of ground-level atmospheric pressure fluctuations

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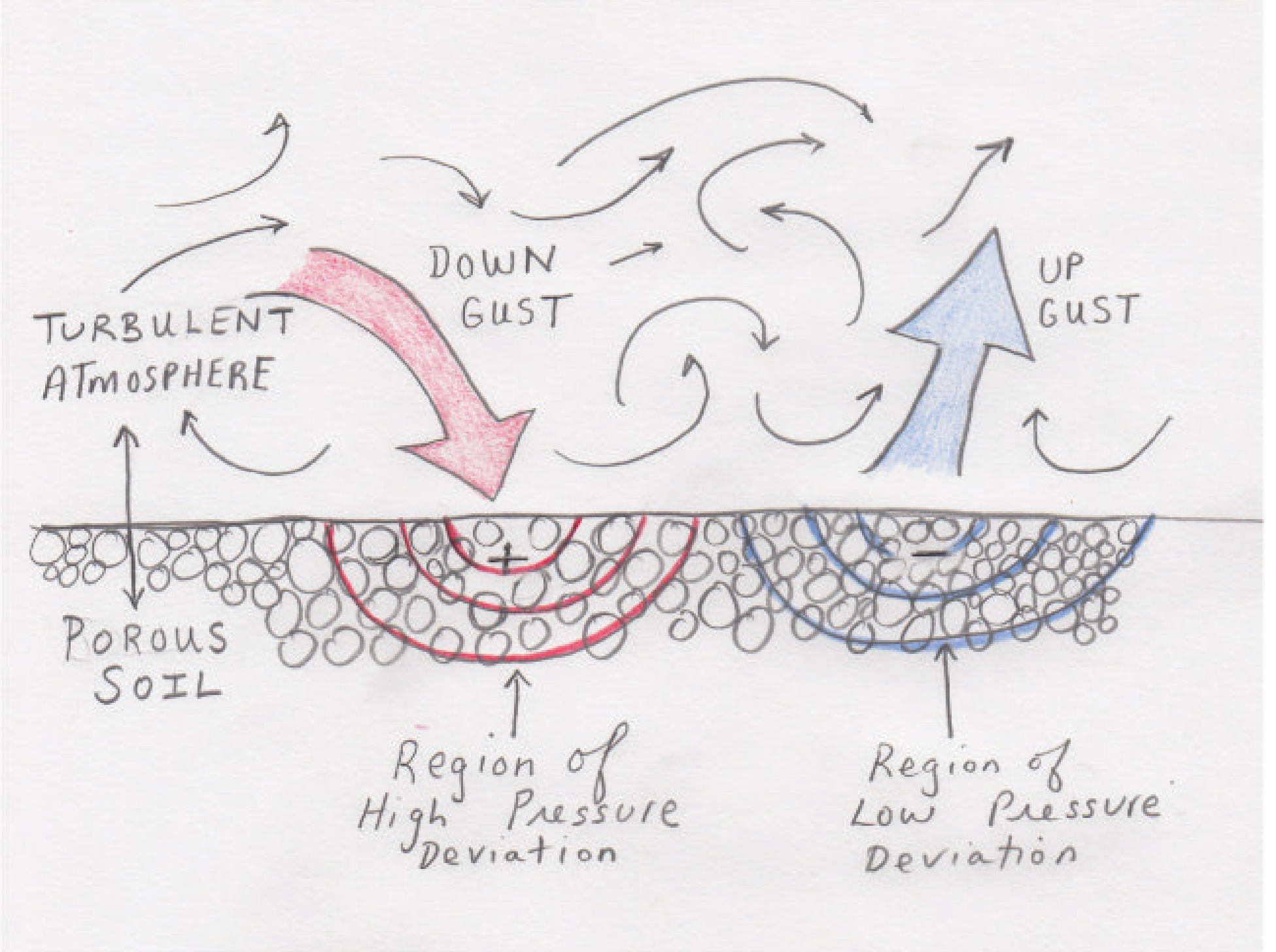
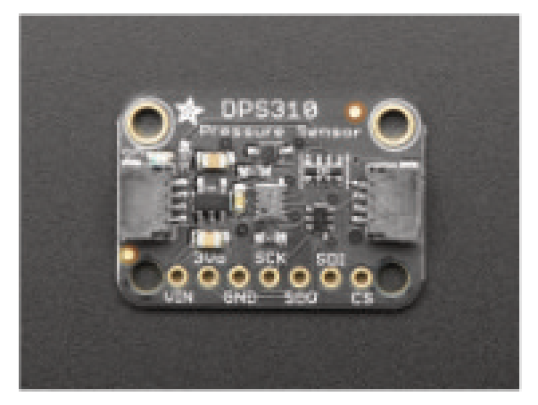
Small changes in barometric pressure at the surface of the Earth induced by everyday turbulence in the lower atmosphere transport trace gases such as water vapor, carbon dioxide, and methane in and out of the soil. This is known as pressure pumping and the ability to monitor and model it is important for understanding the Earth system and predicting climate change.

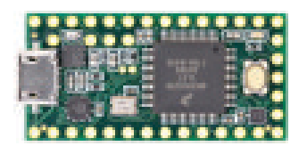


Most observational research on pressure pumping use expensive differential pressure sensors. Due to their cost and complexity, few are in operation.

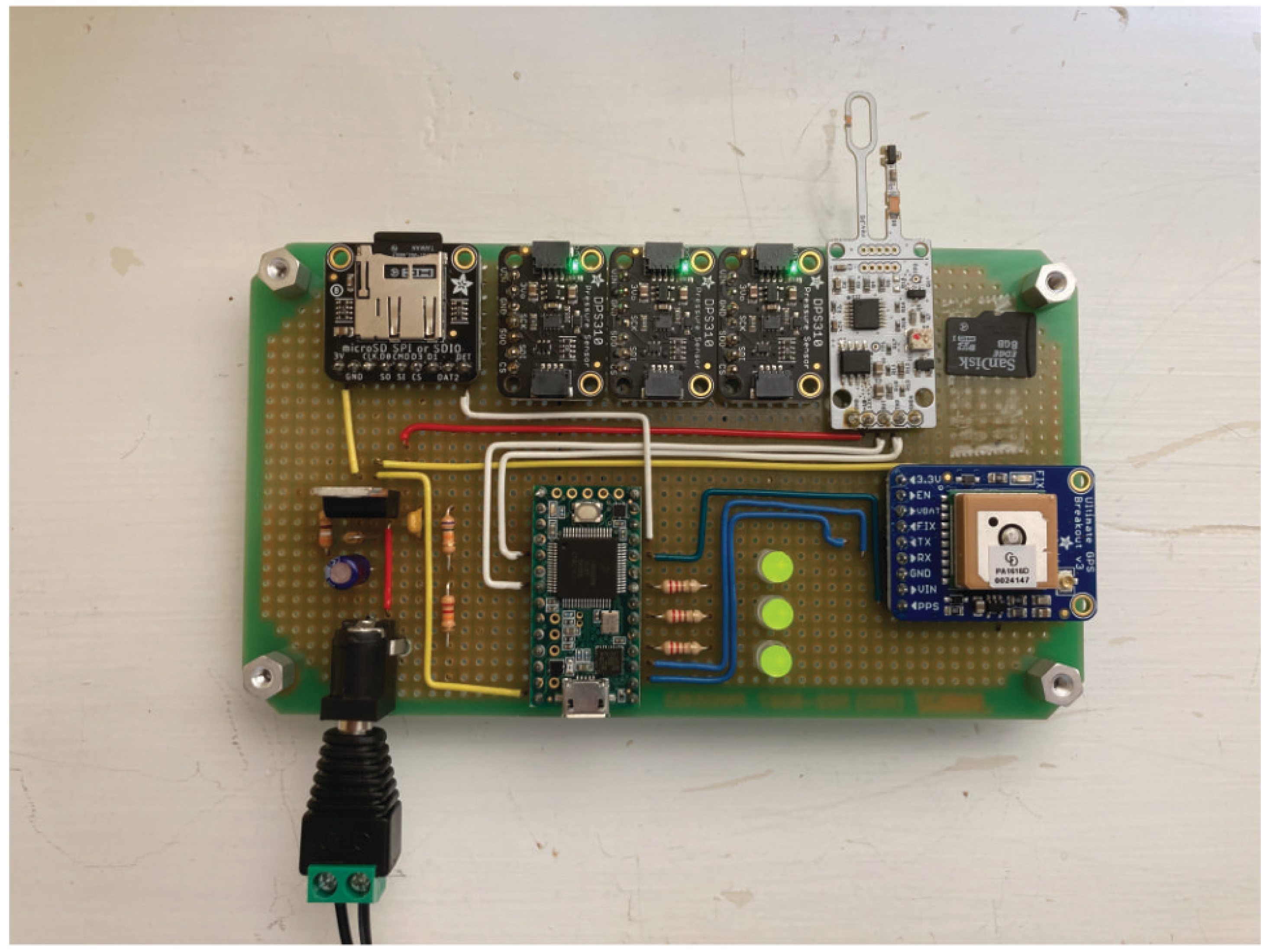
We are testing micromechanical absolute-pressure sensors to explore the possibility of conducting pressure pumping research. The new inexpensive sensors are capable of sensing tiny changes in pressure at subsecond sample rates. We included an anemometer and GPS in the test board as well. The GPS provides accurate time and position data to enable collaboration with others who have independent environmental sensors. The hot-wire anemometer is expected to provide turbulent velocity data near the pressure sensors. The system is small and designed to lay flat on the ground and run off of a common 12V battery while collecting data for many days unattended.



The sensor that we are using is an Infineon DPS310. For this test board we purchased them pre-installed on a breakout board from Adafruit. The manufacturer claims 0.002hPa precision and ±1hPa absolute accuracy.



For our controller, we used a Teensy 3.2.
The 72 MHz Cortex M4 on this board is certainly overkill for the purpose, but more "reasonable" boards are actually more expensive! The Teensy 3.2 is currently out of production, and has been replaced with the Teensy 4.0 which features a Cortex M7 running at 600 MHz for the same price, so overkill will continue in future designs.



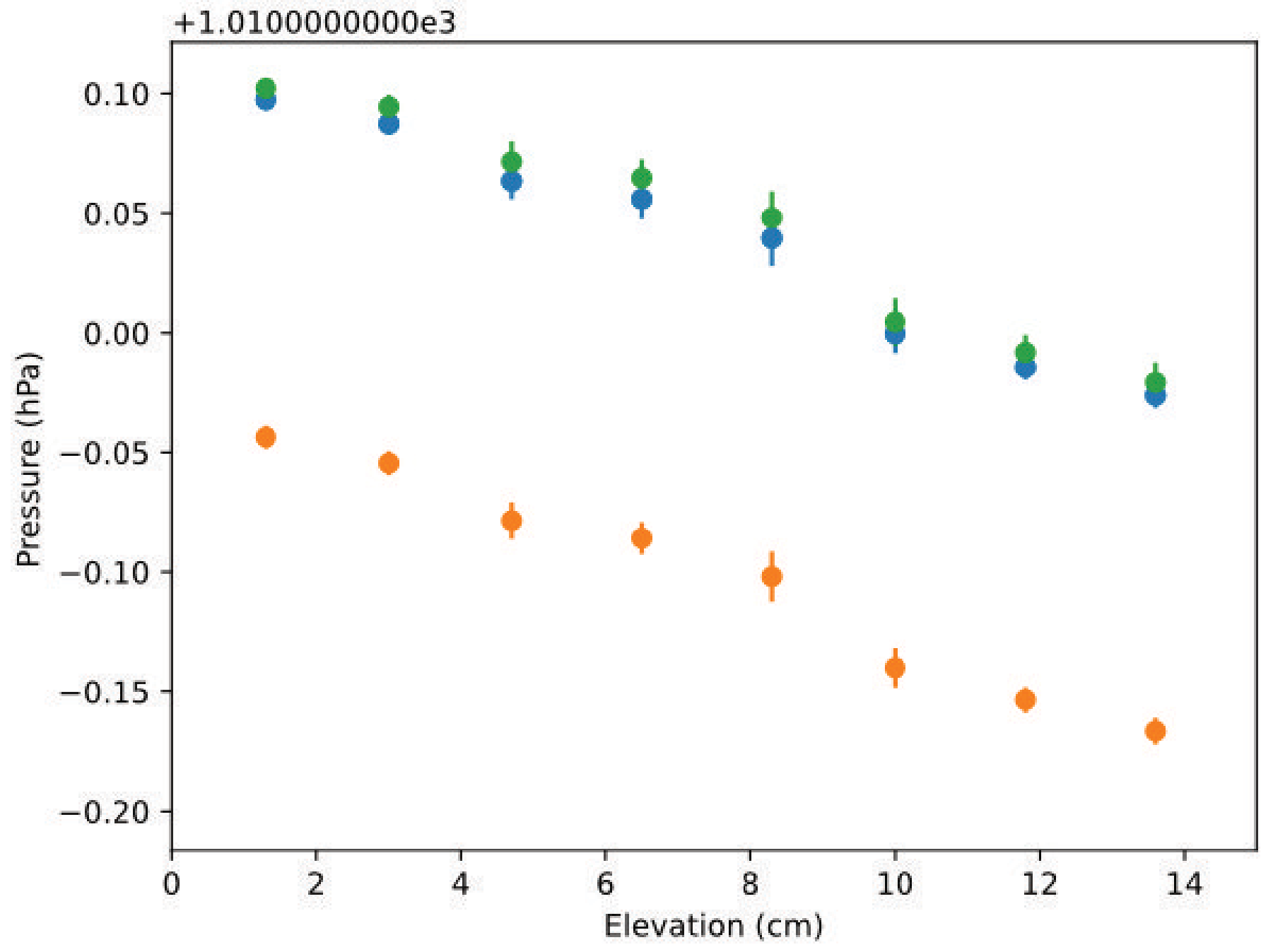
Lacking a reference pressure sensor for direct comparison, we decided to study the ability of these sensors to measure high frequency pressure fluctuations (0.1 to 10 Hz) by sampling three of them, mounted side-by-side, simultaneously at 4 Hz. For some studies absolute accuracy is important, but insights on the spatial and temporal structure of pressure perturbations may be possible with high-precision pressure-fluctuation measurements. As an example, consider that the eddy covariance method, a mainstream technique for measuring turbulent fluxes above the surface, removes the means of the time series before computing covariances of small fluctuations.

If all three of our pressure traces are similar in shape and amplitude, then we may gain some confidence that variations in performance due to manufacturing are not large and that a large number of sensors in a distributed network might be used in the future to study the shape and evolution of pressure perturbations on the surface.

In order to gain confidence that any changes in pressure that we observe are related to ground-level turbulent flow (AKA "wind"), we also installed a hot-wire anemometer close to the pressure sensors.

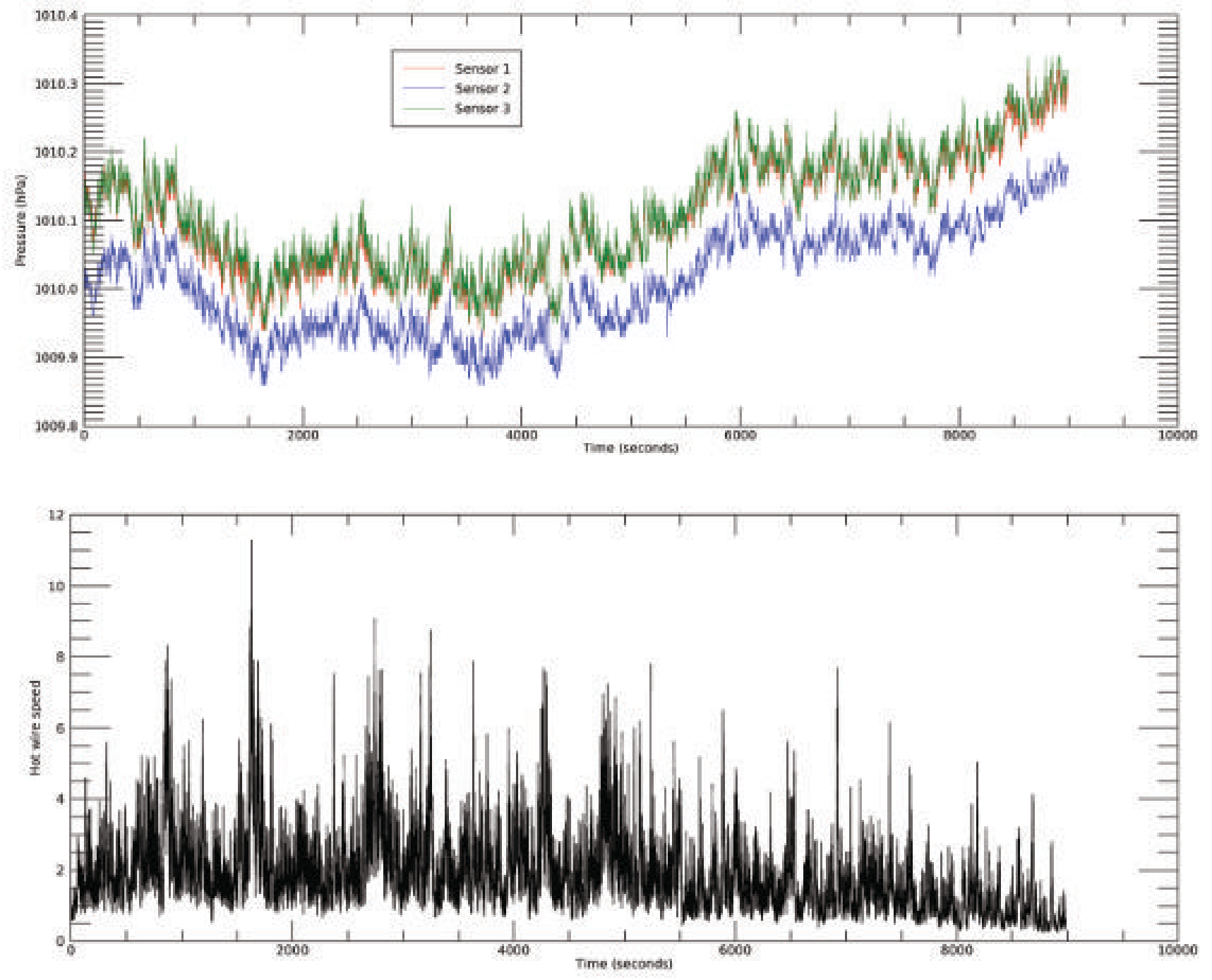
In order to compare our data with sensors from future collaborators, and to provide the capability to synchronize data from multiple units in future research, we employed a GPS to provide accurate times in the data records. (The GPS also adds the advantage of logging the location of the sensor.)

Does it work? Looks promising!



To verify that these sensors were able to do what was needed, we recorded pressure measurements as we increased the height of the instrument. (Yes, the total elevation change in this graph is just 15 cm!)

This initial data looks promising. The three sensors did not precisely agree on *absolute* pressure; they differed by about 15 Pa. But they tracked pressure *changes* very consistently with almost perfect agreement.



A long data run in environmental conditions (AKA "outside on the dirt") reveals a wealth of data and definite correlations between wind events and pressure-fluctuation changes.

This device shows definite promise as a tool for pressure-pumping research, and we will be collaborating further with the land-air interface research community.