Evaluation of the Infineon DPS310 for Observations of Turbulent Pressure Perturbations

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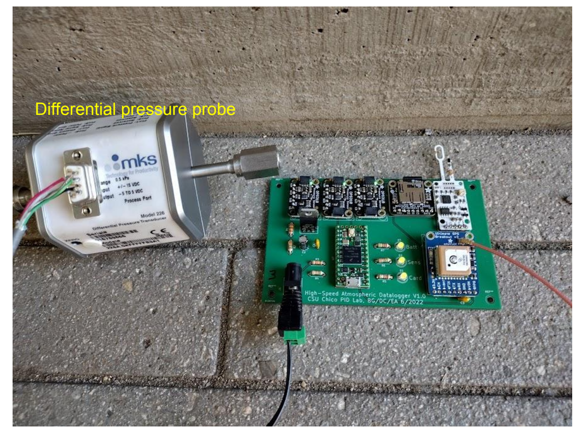
Why are turbulent pressure perturbations important?

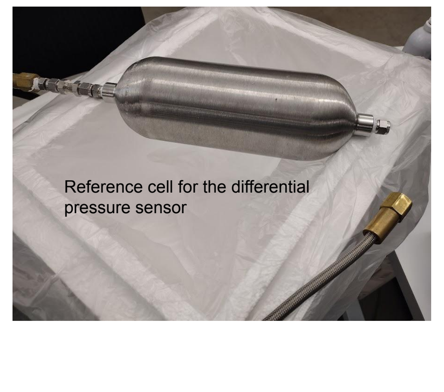
Atmospheric pressure variations (or perturbations, P') near the earth's surface are extraordinarily dynamic and understanding them is essential to understanding how atmospheric phenomena exchange energy, momentum and mass with the biosphere. On the scale of global circulation models and weather forecast models atmospheric pressure is key to parameterizing the surface drag, a key component of all atmospheric models. P' are also integral to certain types of short term (non-synoptic) atmospheric phenomena, such as high frequency gravity waves, lower frequency inertia-gravity waves, solitons, atmospheric density currents, and high frequency coherent structures that strongly influence surface drag as determined from the interaction between the wind, the wind shear and plant canopies.

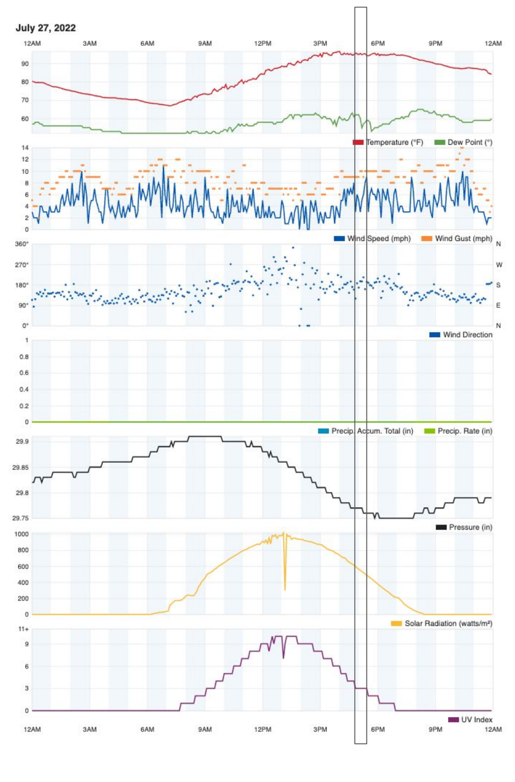
Understanding and modeling this phenomenon are important because such air currents can influence key physical and biological processes in the soil and snowpacks through their ability to modify concentration profiles and advective fluxes of gases within and through the pore spaces of these permeable media. For example, these air current transport O_2, CO_2 through both soils and snowpacks, water vapor, CH_4, N_2O, gaseous radioactive contaminants, Hg vapor, isotopes of Rn, and He. Furthermore, this transport mechanism influences the rate of evaporation of soil water, the sublimation rate of snowpacks, and the volatilization rates and fate of soil contaminants, such as jet fuel or other soil contaminants. In addition, knowledge of the advective velocities induced by pressure pumping may help improve the long term measurements of ecosystem CO2 fluxes and carbon balance, the formulation of the soil surface boundary condition for land surface (soil-plant-atmosphere), the fluxes of soil-generated greenhouse gases for climate studies, the transport and deposition of combustion products into the soil during prescribed fires , and the exchange of atmospheric gases between the atmosphere and (a) cavities (e.g., mines, shafts, quarries, wells) within the Earth's surface and (b) topographical features (e.g., snow drifts, sand dunes, furrows) on the Earth's surface. Clearly, pressure pumping is an important and significant mode of the exchange between the vadose zone and the atmosphere (Massman and Frank, 2022).

Comparison with the mks Model 226 differential pressure probe on July 27, 2022

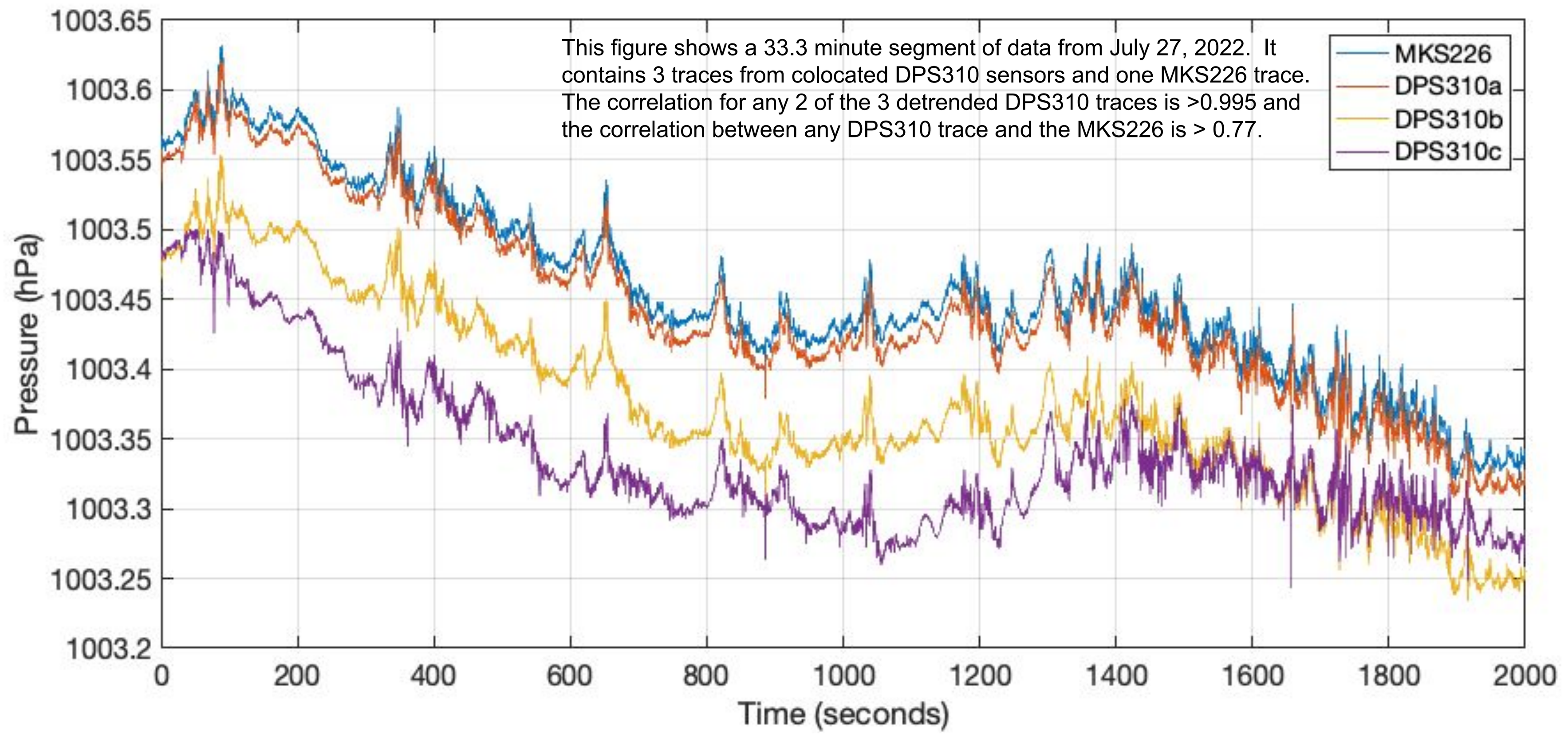


On July 27, 2022, we operated three DPS310s next to a mks Model 226 differential pressure probe in the breezeway of the Chico State 4-story science building. We put the reference cell of the mks Model 226 in a styrofoam cooler filled with ice to stabilize it. The weather was sunny and hot and winds from the weather station on the top of the building were from the west gusting to 4.5 m/s. The funneling effect of the building through the breezeway may have contributed to large pressure perturbations.

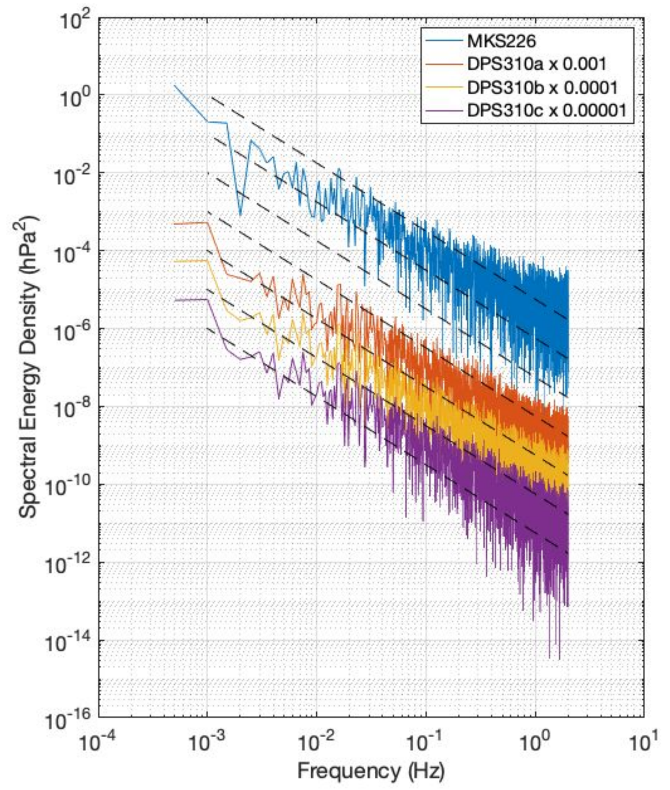




Above: Data from Science Building Rooftop weather station (KCACHICO248)

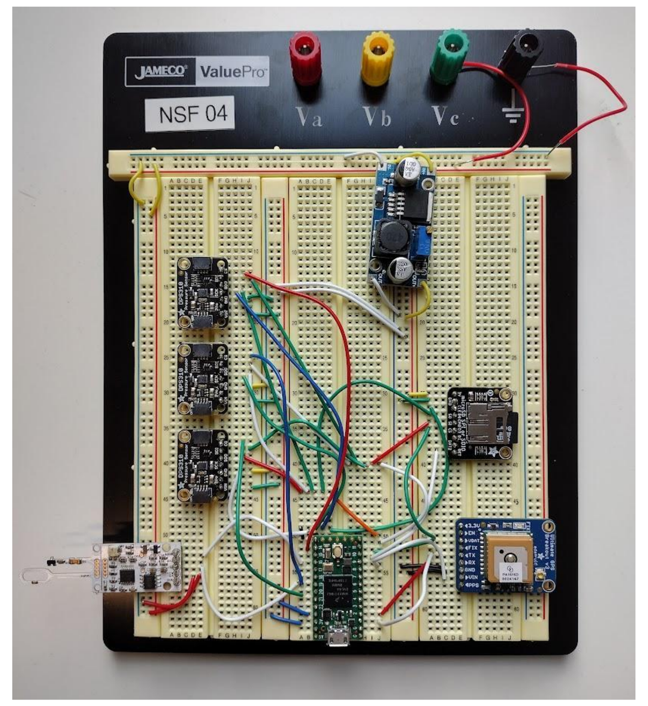


The figure below shows variance as a function of frequency (f) for each of the time-series traces to the left (after detrending and tapering). The dashed lines are $f^{-5/3}$. It demonstrates that the fluctuations are consistent with a Kolmogorov inertial subrange spectrum for turbulence.



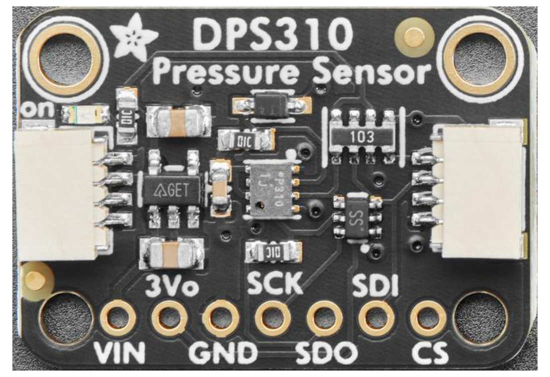
Above: Although the accuracy of any individual sensor is not great, the precision and responsivity appears sufficient to resolve turbulent perturbations.

The technology



Infineon DPS310: According to the manufacturer's data sheet, "The pressure sensor element is based on a capacitive sensing principle which guarantees high precision during temperature changes."

Sensor size: 2 mm by 2.5 mm by 1.0 mm



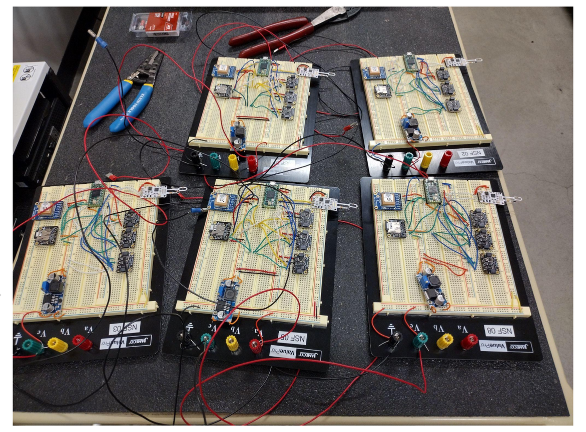
We purchased Adafruit part number 4494 that made use of the DPS310 much easier.

We purchased the above sensors mounted on breakout boards from Adafruit Industries (part number 4494) to speed our testing.To help determine whether high-frequency pressure fluctuations are real coherent signals or random noise, we mounted three 4494s side-by-side and sampled them with a PJRC Teensy 4.0 microcontroller. The 3 pressure ports are in a line approximately 18 mm apart. Our custom device includes a GPS module (Adafruit part number 5440) and a hot wire anemometer (Modern Device Wind Sensor Rev. P). The GPS module provides accurate time information (to within 1 s) to facilitate comparison with other sensors and the hot wire anemometer provides wind speed within a few centimeters of the pressure sensors. The pressure sensors and hotwire are sampled at 4 Hz and the data are saved to an SD memory card in a text file. The system is powered by 12V DC.

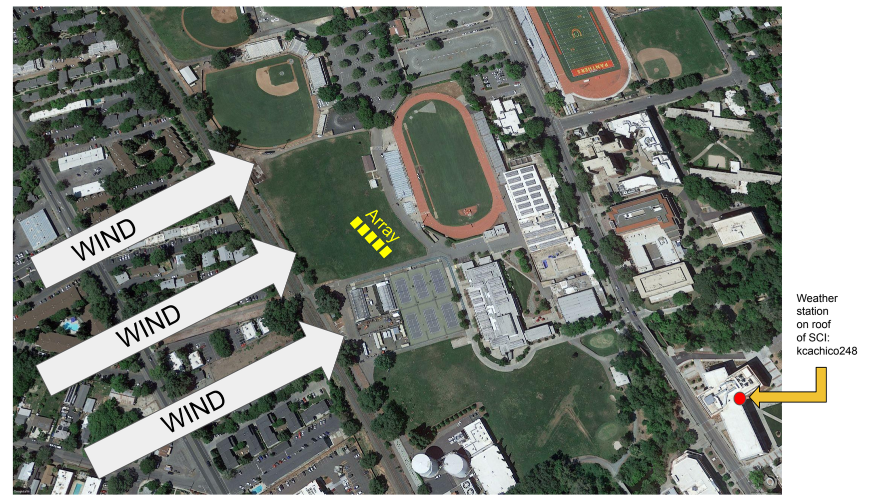
Ultimately, we would like to measure the pressure at a point in space over time that would exist if the sensor were not there. However, pressure sensors installed above the surface (for example, on a tower) alter the pressure field due to the airflow around the sensor. The use of specially designed "static pressure ports" (left) can minimize this effect (Nishiyama and Bedard, 1991). To eliminate the need of static pressure ports in our work, we chose to lay the pressure sensors flat on the ground with the sensor port facing up. In this way, they do not obstruct flow and blend in with the roughness elements on the surface of the Earth. We hypothesize that the surface pressure perturbations we detect minimally influenced by the device itself when laying flat on the surface.

Example application: Spatiotemporal observations of pressure perturbations on December 28, 2022

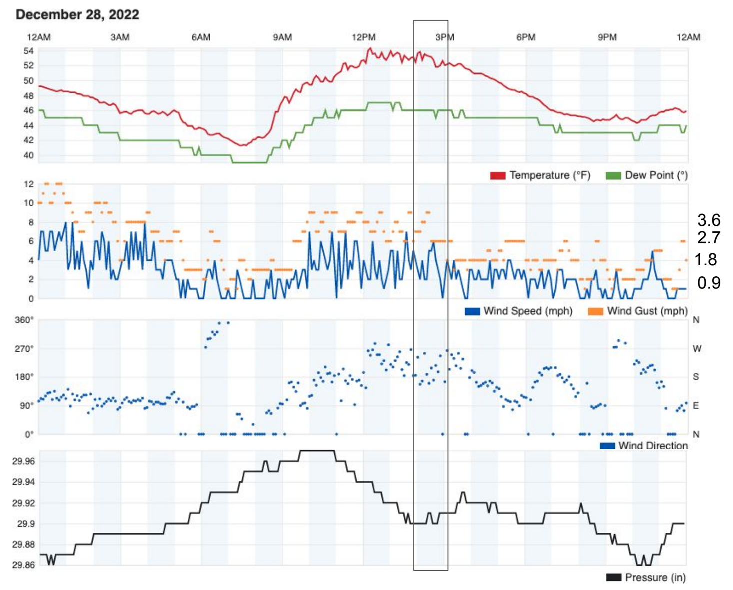
During the fall semester, we built 5 systems with buck converters and solderless breadboards. On December 28, 2022, we deployed them in a line spaced 10 m apart on a Chico State athletics field. We oriented the line to be perpendicular to the mean wind direction (SW).

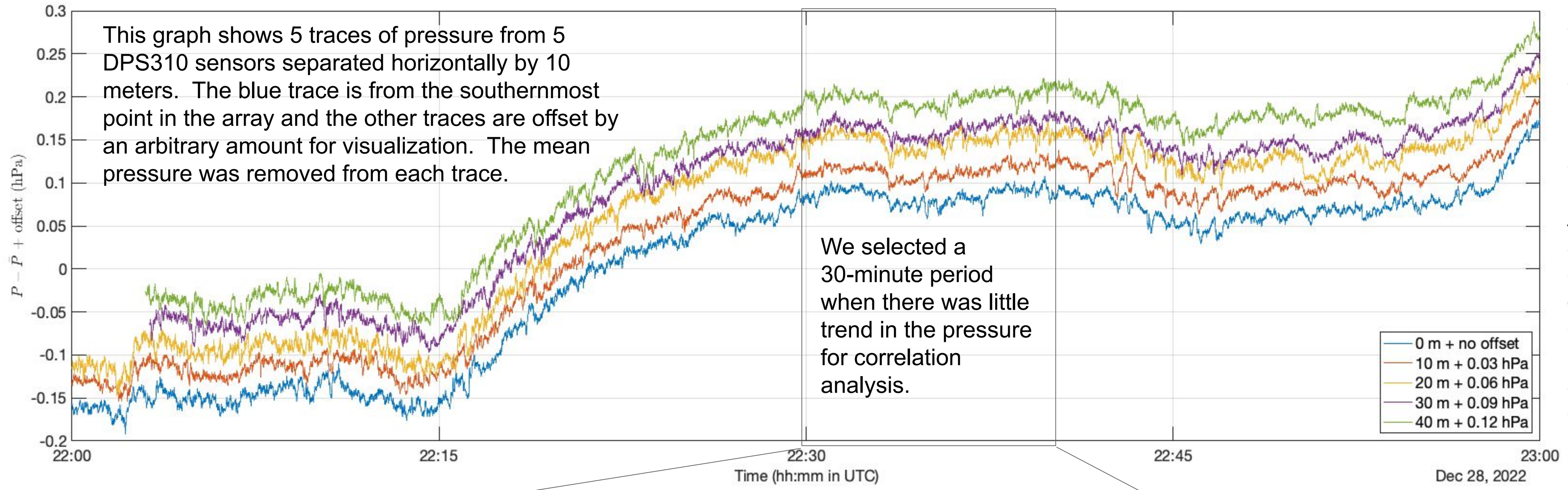


In the first and last system in the line, 1 of 3 pressure sensors failed for an unknown reason. Hotwire anemometers failed in 3 of the 5 systems. Analysis of the hotwire sensors and data is ongoing. Plots to the right are from 1 of 3 sensors at each location in the array.



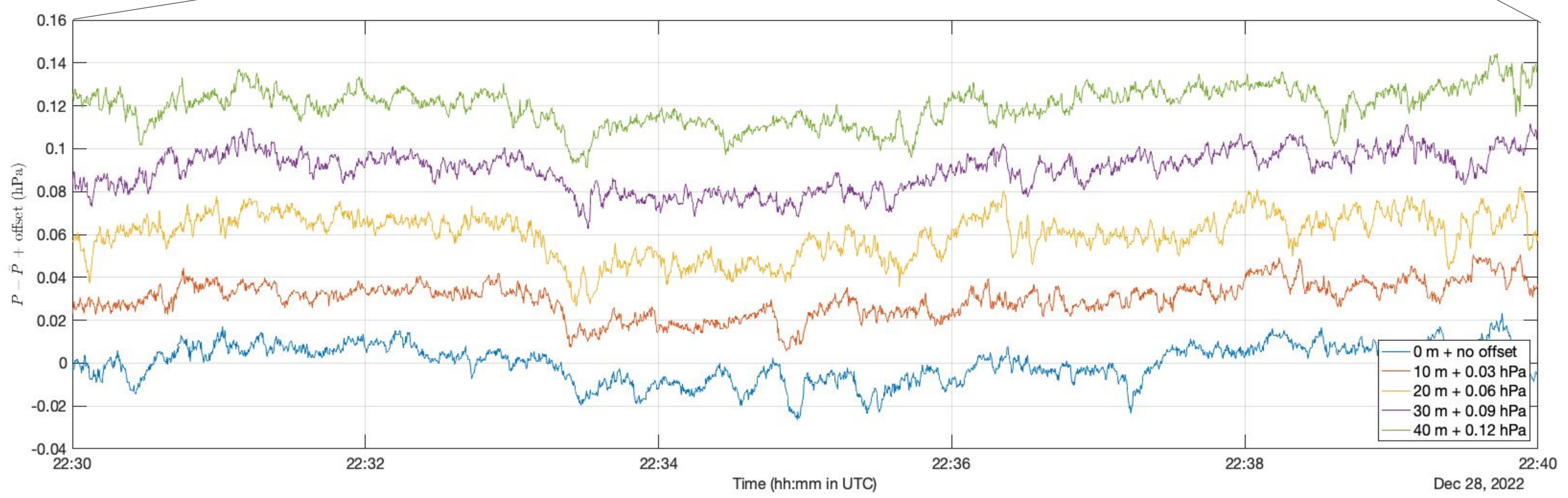
During the 1 hour of data collection shown to the right, winds very very light. Wind speeds on the roof of the science building ranged from 0-4 m/s and the direction ranged from southerly to westerly.

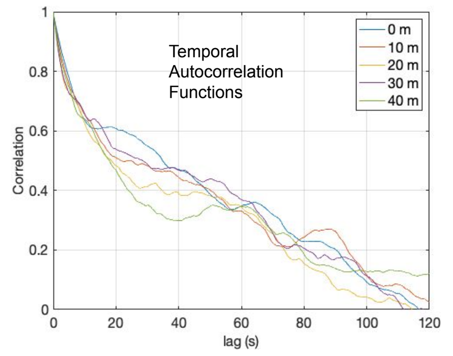


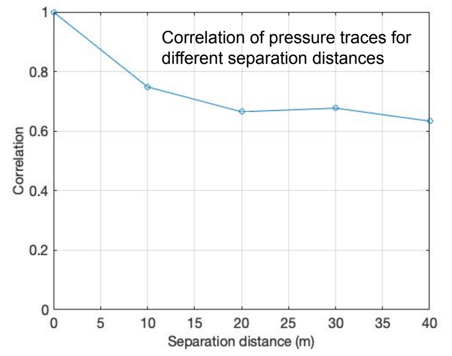


BELOW: Our data analysis shows that the integral time scale for pressure perturbations is about 2 minutes.

At 40 meter separation, the correlation dropped to about 0.63. The integral length scale must be considerably larger.







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Acknowledgements: This research was supported under NSF 2054969.
Thanks to Dr. Christoph Senff for pointing out the more sensitive version of the sensor used.