Continued Development and Testing of a Sensor For Ground-level Measurement of Microscale Atmospheric Pressure Fluctuations

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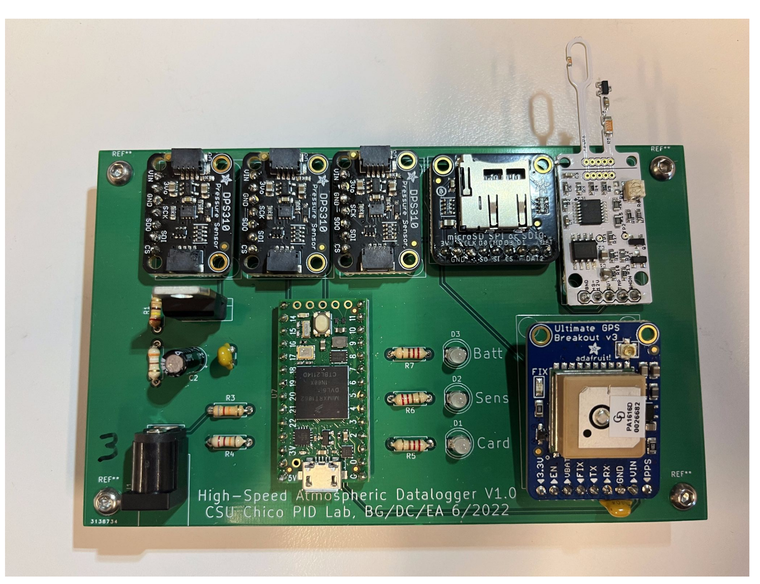
MOTIVATION

Very small, high-frequency fluctuations in barometric pressure play important roles in the physics of turbulence and the environment. For example, pressure fluctuations are responsible for making turbulence isotropic at small scales (Kraichnan 1959) and they are responsible for transporting trace gases in and out of permeable soil (Laemmel et al. 2017)

BACKGROUND

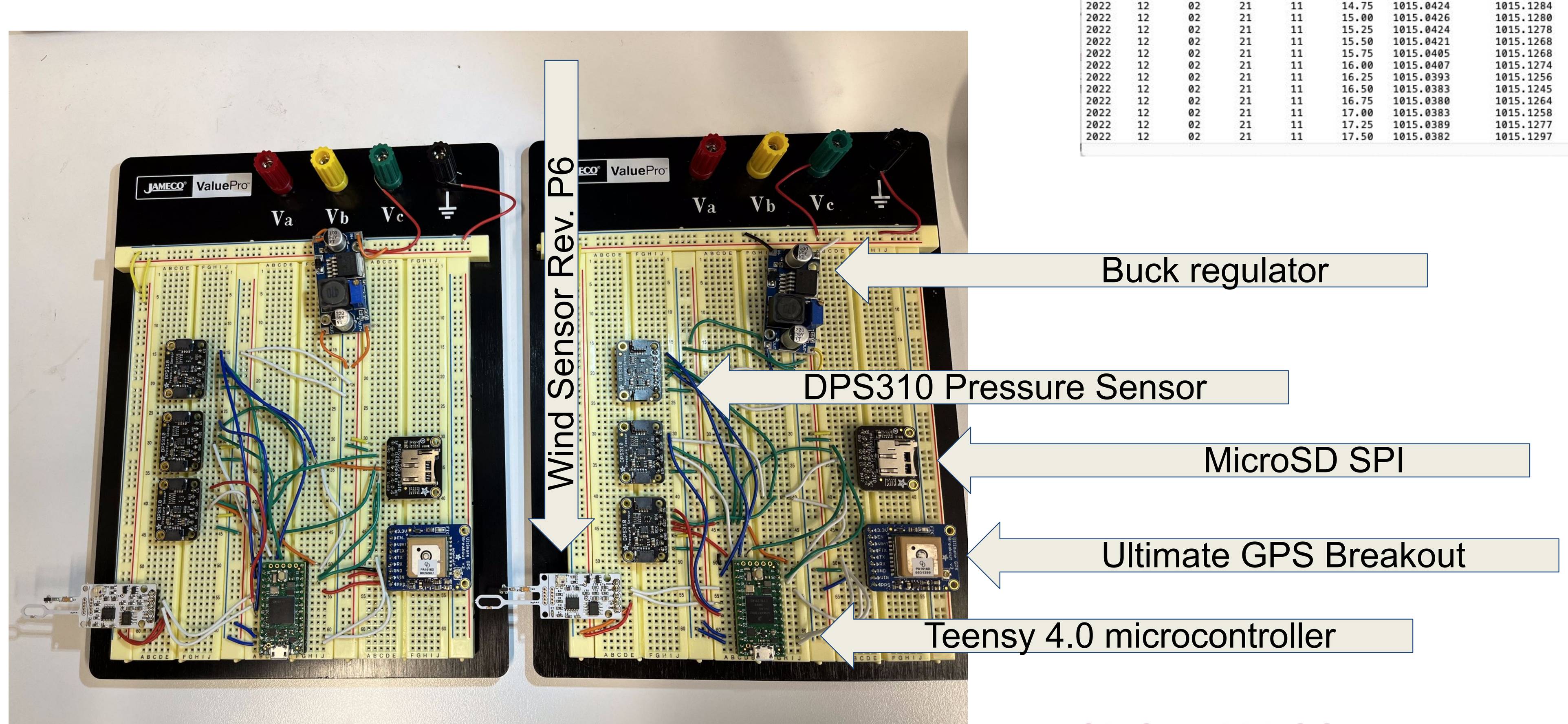
Mayor and Ayars developed a sensor suite to record very small fluctuations in barometric pressure near the ground.The new technology is the Infineon DPS310 sensor. Three of them are used simultaneously to confirm that pressure fluctuations are real and not noise.



Several of the sensor suites were constructed but the linear voltage converter used became dangerously hot.

MODIFICATIONS TO SENSOR SUITE

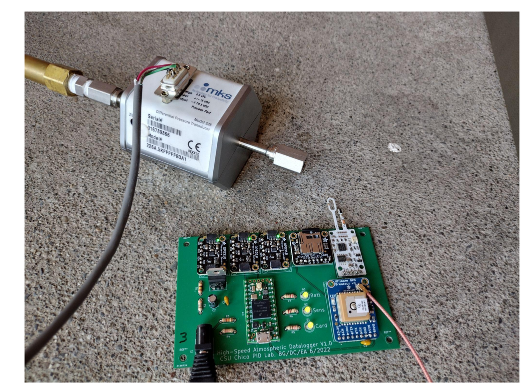
In my work, I replaced the linear voltage regulator with a Buck converter in an effort to eliminate the hot voltage regulator. I built two of the sensor suites on solderless breadboards shown below.

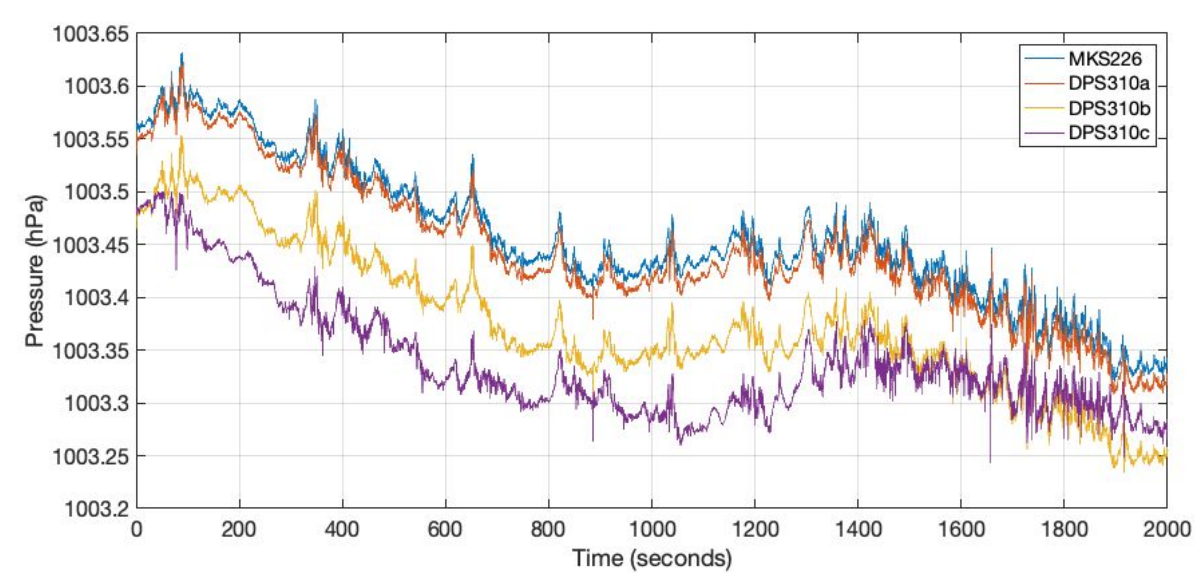


Above: Two pressure sensor suites built by Kevin Scheive during F22.

PRIOR RESULTS (VALIDATION of FLUCTUATIONS)

In the summer of 2022, Efrain Cobian collected the following data showing that the pressure fluctuations agreed with those measured by a reference differential pressure probe provided by Drs. John Frank and Bill Massman (USFS, Fort Collins, CO)



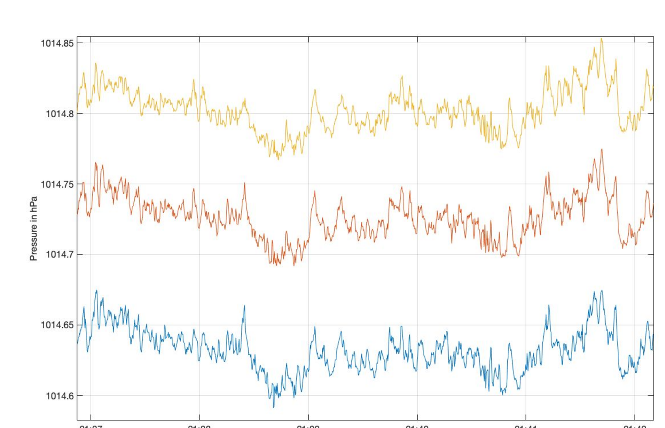


RESULTING DATA FILE SAVED ON SD CARD

The 3 pressure sensors, GPS, and hotwire anemometer are sampled at 4 Hz and the data are written to an ASCII text file on an SD memory card. Below is an example of 1 data file.

west_side_data030.txt — Edited

Year	Month	Day	Hour	Minute	Second	PRESSURE A	PRESSURE B	PRESSURE C	TEMP A	TEMP B	TEMP C	WIND Speed	WIND TEMP	Latitude	Longitude	SUPPLY Voltage
2022	12	02	21	11	10.00	1015.0301	1015.1167	1015.0401	16.54	16.66	15.81	0.800	9.76	39.7288150	-121.8472367	14.46
2022	12	02	21	11	11.00	1015.0297	1015.1188	1015.0421	16.54	16.66	15.81	0.684	9.34	39.7288150	-121.8472467	14.46
2022	12	02	21	11	11.25	1015.0306	1015.1213	1015.0416	16.54	16.65	15.81	0.767	9.55	39.7288150	-121.8472467	14.45
2022	12	02	21	11	11.50	1015.0324	1015.1183	1015.0429	16.55	16.63	15.81	0.694	9.10	39.7288150	-121.8472467	14.45
2022	12	02	21	11	11.75	1015.0338	1015.1189	1015.0438	16.54	16.63	15.81	0.715	9.14	39.7288150	-121.8472467	14.47
2022	12	02	21	11	12.00	1015.0350	1015.1187	1015.0444	16.53	16.62	15.80	0.665	9.14	39.7288150	-121.8472433	14.46
2022	12	02	21	11	12.25	1015.0351	1015.1208	1015.0444	16.52	16.62	15.81	0.699	9.30	39.7288150	-121.8472433	14.45
2022	12	02	21	11	12.50	1015.0337	1015.1199	1015.0452	16.52	16.61	15.81	0.675	8.48	39.7288150	-121.8472433	14.47
2022	12	02	21	11	12.75	1015.0370	1015.1191	1015.0437	16.52	16.60	15.80	0.675	9.34	39.7288150	-121.8472433	14.47
2022	12	02	21	11	13.00	1015.0394	1015.1208	1015.0449	16.53	16.61	15.79	0.617	9.22	39.7288150	-121.8472467	14.46
2022	12	02	21	11	13.25	1015.0399	1015.1234	1015.0446	16.52	16.62	15.79	0.650	9.80	39.7288150	-121.8472467	14.46
2022	12	02	21	11	13.50	1015.0425	1015.1269	1015.0444	16.53	16.61	15.78	0.705	9.72	39.7288150	-121.8472467	14.46
2022	12	02	21	11	13.75	1015.0427	1015.1269	1015.0457	16.53	16.62	15.78	0.916	9.59	39.7288150	-121.8472467	14.45
2022	12	02	21	11	14.00	1015.0432	1015.1269	1015.0460	16.54	16.61	15.78	0.992	10.17	39.7288150	-121.8472533	14.46
2022	12	02	21	11	14.25	1015.0430	1015.1259	1015.0475	16.53	16.61	15.78	1.385	9.76	39.7288150	-121.8472533	14.46
2022	12	02	21	11	14.50	1015.0421	1015.1285	1015.0490	16.52	16.60	15.78	1.290	10.13	39.7288150	-121.8472533	14.45
2022	12	02	21	11	14.75	1015.0424	1015.1284	1015.0513	16.51	16.60	15.78	0.998	9.96	39.7288150	-121.8472533	14.46
2022	12	02	21	11	15.00	1015.0426	1015.1280	1015.0514	16.53	16.60	15.78	0.923	10.54	39.7288100	-121.8472533	14.45
2022	12	02	21	11	15.25	1015.0424	1015.1278	1015.0518	16.52	16.61	15.77	0.767	9.92	39.7288100	-121.8472533	14.45
2022	12	02	21	11	15.50	1015.0421	1015.1268	1015.0511	16.52	16.60	15.76	0.675	9.72	39.7288100	-121.8472533	14.46
2022	12	02	21	11	15.75	1015.0405	1015.1268	1015.0542	16.50	16.60	15.77	0.665	9.84	39.7288100	-121.8472533	14.46
2022	12	02	21	11	16.00	1015.0407	1015.1274	1015.0538	16.50	16.59	15.77	0.800	9.67	39.7288067	-121.8472450	14.47
2022	12	02	21	11	16.25	1015.0393	1015.1256	1015.0514	16.50	16.58	15.76	0.935	9.88	39.7288067	-121.8472450	14.46
2022	12	02	21	11	16.50	1015.0383	1015.1245	1015.0526	16.49	16.57	15.76	0.646	10.09	39.7288067	-121.8472450	14.46
2022	12	02	21	11	16.75	1015.0380	1015.1264	1015.0535	16.49	16.58	15.76	0.551	9.43	39.7288067	-121.8472450	14.46
2022	12	02	21	11	17.00	1015.0383	1015.1258	1015.0516	16.48	16.58	15.75	0.735	9.80	39.7288017	-121.8472383	14.47
2022	12	02	21	11	17.25	1015.0389	1015.1277	1015.0543	16.48	16.59	15.76	0.564	10.46	39.7288017	-121.8472383	14.45
2022	12	02	21	11	17.50	1015.0382	1015.1297	1015.0529	16.47	16.60	15.74	0.599	10.75	39.7288017	-121.8472383	14.46



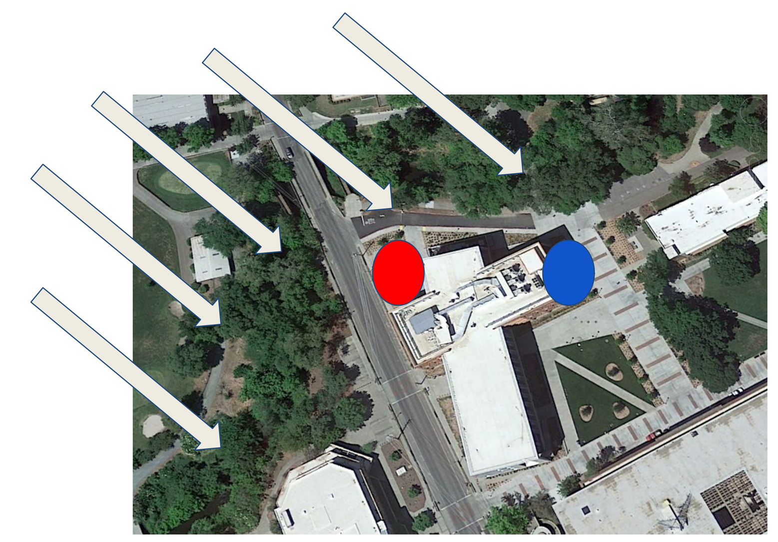
Detailed view of three DPS310 sensors from Dec. 2 experiment

LONG TERM GOAL

Our goal is to construct a set of sensor suites (at least 9) and deploy them in an array to measure the correlation of pressure fluctuations as a function of distance.

NEW EXPERIMENT: PRESSURE DEVIATIONS AROUND SCIENCE BUILDING

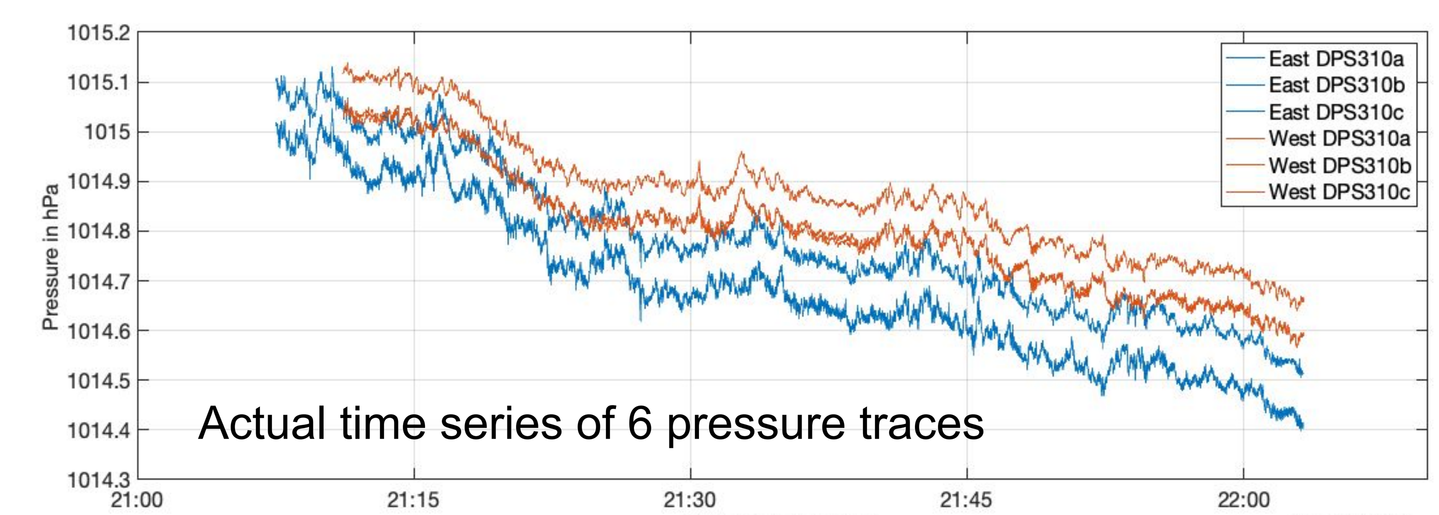
We conducted an experiment on December 2, 2022 to see if we could detect building-induced pressure fluctuations. We deployed one of the two new sensor suites on the west side the building and the second on the east side of the building.

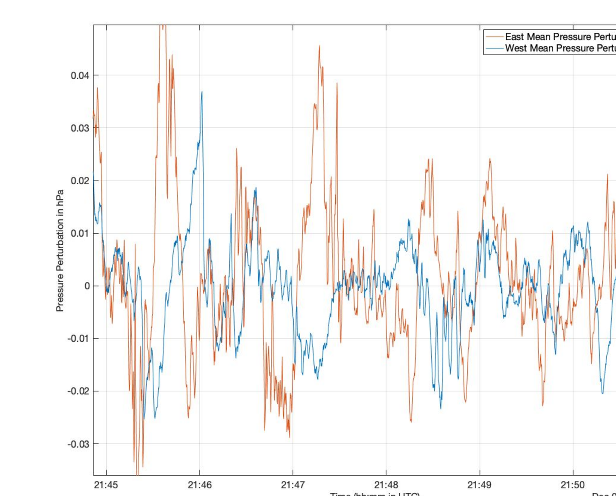


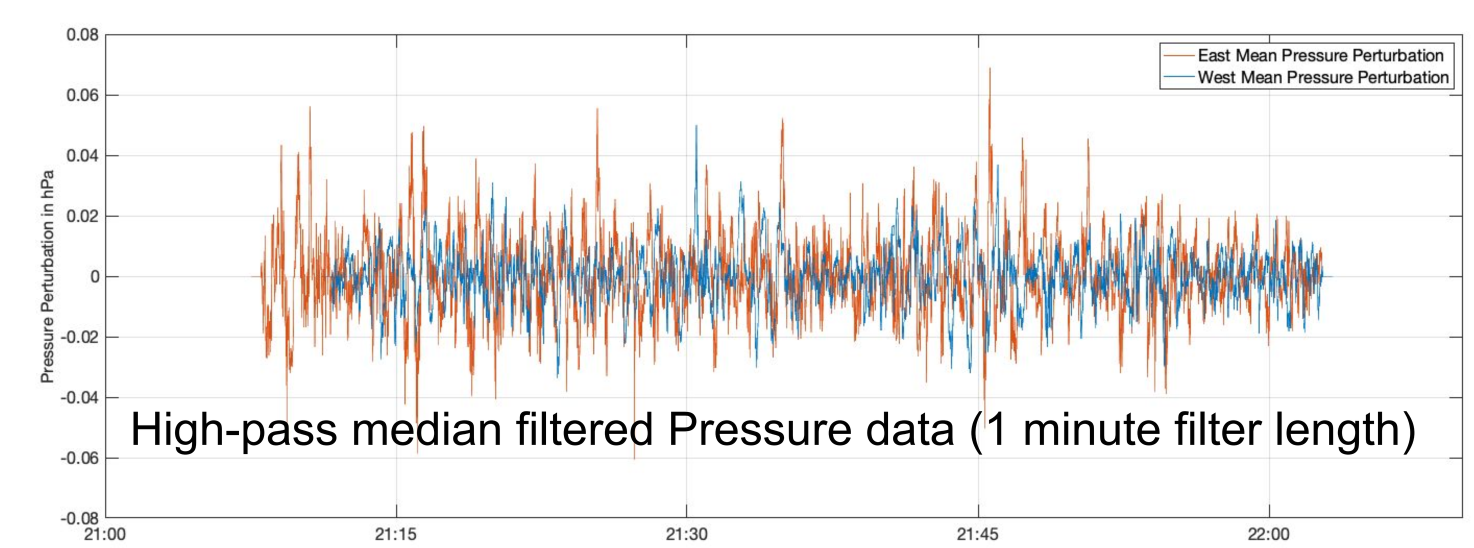
WEST SIDE

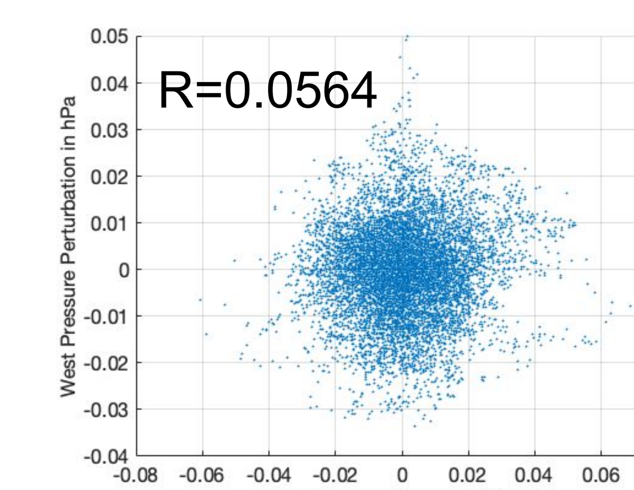
EAST SIDE

Hypothesis: because the wind was blowing from the NW, we expect positive pressure deviations on the west side of the building and negative pressure deviations on the east side of the building.









Scatterplot of pressure perturbations

CONCLUSION

When looking at the time series carefully, we do find periods when the pressure perturbations are anticorrelated as we hypothesized. However, the correlation coefficient for the full 52 minute segment shown above (containing 12,500 points) is only 0.0564. The results show no correlation.

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- Kraichnan, R. H., 1959: The structure of isotropic turbulence at very high Reynolds numbers, J. Fluid Mech. 5, 497.
- Laemmel, T., Mohr, M., Schack-Kirchner, H., Schindler, D. and Maier, M., 2017: Direct Observation of Wind-Induced Pressure-Pumping on Gas Transport in Soil. Soil Science Society of America Journal, 81: 770-774.
- Mayor, S. D., E. Ayars, E. Cobian, J. M. Frank, and W. J. Massman, 2023: Evaluation of the Infineon DPS310 for observations of turbulent pressure perturbations. Abstract for poster presentation submitted to the 24th Symposium on Boundary Layers and Turbulence, American Meteorological Society, Tues., Jan. 10, Denver, Colorado.