Measuring Heat Leakage

via a Drone Mounted Sensor Package

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Background

- There are a multitude of historical buildings throughout campus
- With buildings of this age, we expect to find significant heat leakage through their rooftops
- How can we measure this?

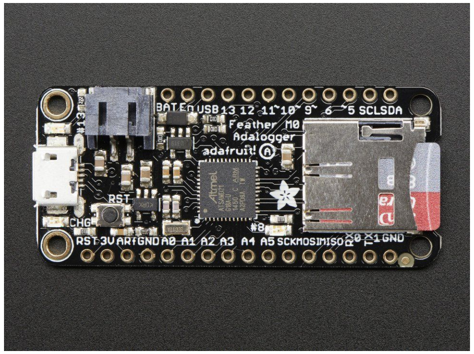
Experimental Design

- We need a method for exploring the rooftops
  - Bring in the drone
- Develop a method for measuring temperature across the rooftop
  - We needed to keep track of both temperature and location

Devices Used

- MLX 90614 - IR sensor used to measure temperature based on radiation from roof's surface
- Ultimate GPS - used to gather position data, such as latitude and longitude
- VL53L0X - IR sensor used to measure distance to rooftop surface based on reflection from roof's surface
- BME 680 - measures temperature, humidity, pressure, and elevation

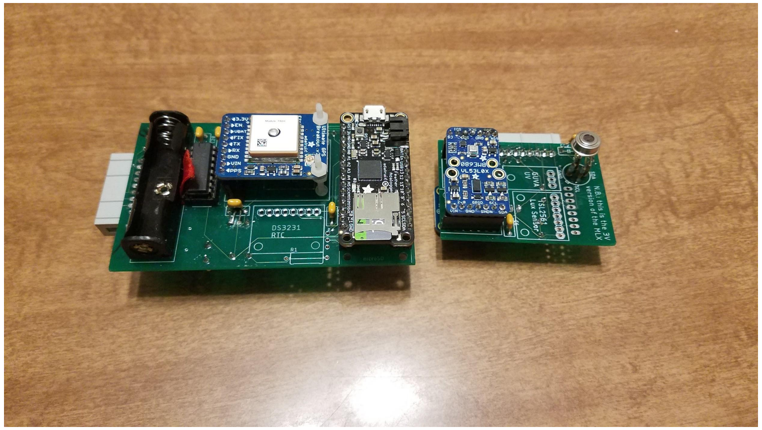
About our Processor

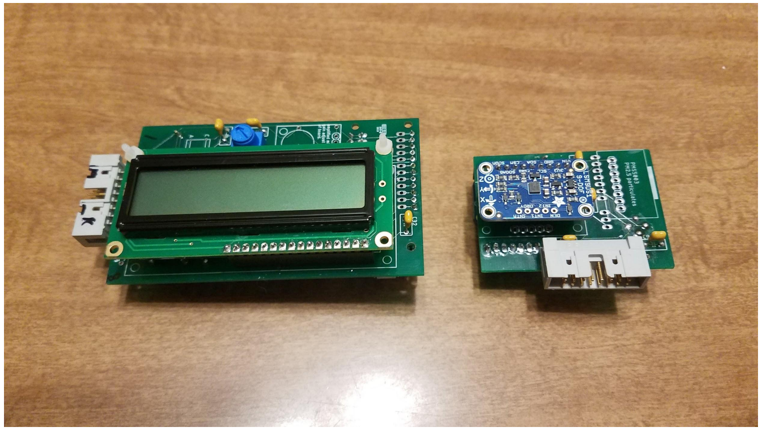


- In order to account for the size constraints of the drone we had to switch from the Arduino Mega 2560 to a smaller processor
- We chose to use the Adalogger Feather M0, which is considerably smaller than the Mega
- The Adalogger has an onboard SD card reader which allowed us to avoid using an SD breakout board

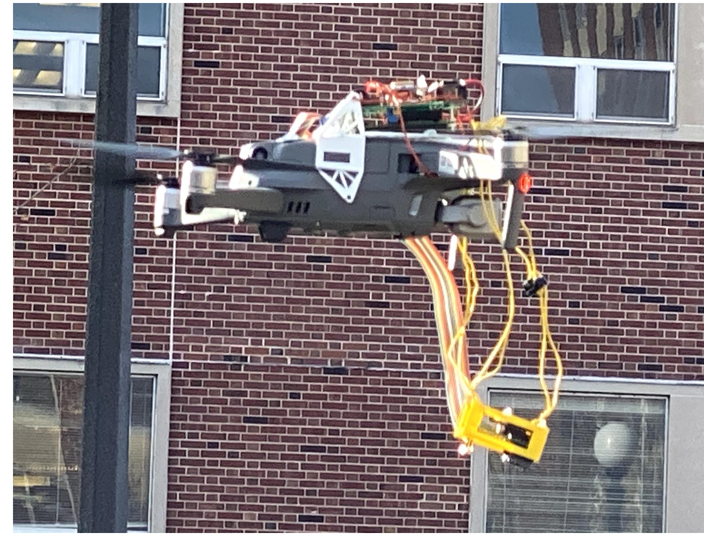
Getting in the Air

- In order to get our sensors onto our drone we had to take a few steps
  1. We had to use a printed circuit board small enough to fit on the drone both on top of it and hanging below it
  2. We also had to create a mount for the drone that could carry our sensor package.





Getting in the Air



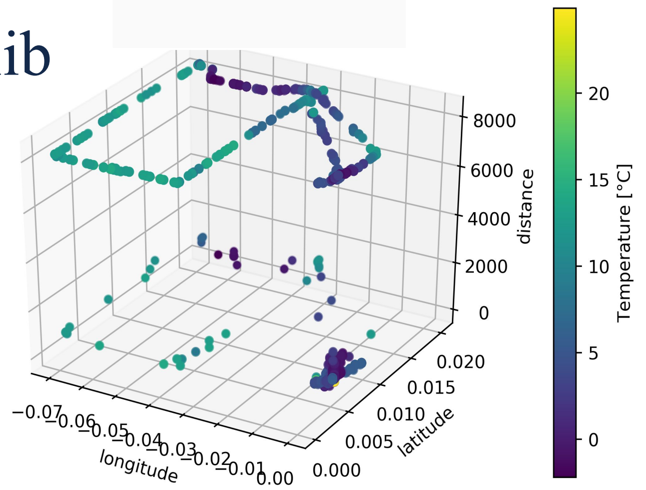
Data Acquisition

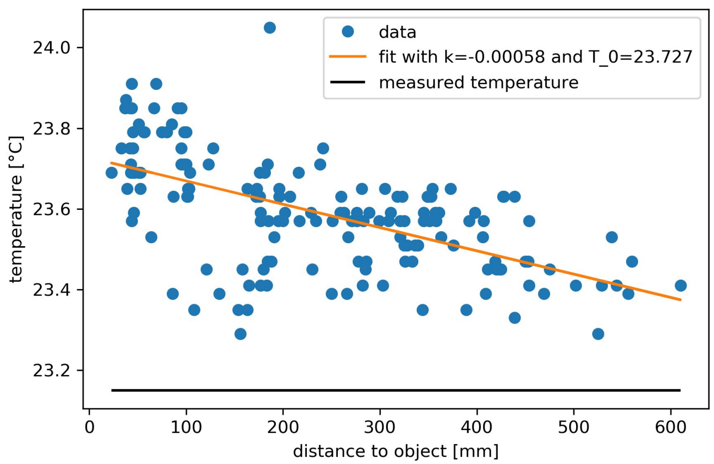
- Going from Arduino Mega to the Adalogger
  → only minor differences
- DAQ divided in:
  initialization, setup and loop
- data format for python pandas

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	latitude	longitude	GPS_altitu	GPS_hour	GPS_minu	GPS_secoı	mlx_ambi	mlx_objec	vlx_distar	bme_tem	bme_altitude	bme_pressure	bme_humidity	bme_gas
2	0	0	0	0	0	7	22.41	22.19	667	21.77	142.85	996.21	32.24	54.47
3	0	0	0	0	0	7	22.37	23.23	160	22.02	142.51	996.25	32.29	100.25
4	0	0	0	0	0	8	22.39	22.13	388	22.33	142.51	996.25	32.25	135.8
1413	4006.648	8813.382	240.4	16	36	52	7.19	10.17	8190	8.84	148.08	995.59	68.2	808.78
1414	4006.648	8813.383	240.4	16	36	53	7.11	9.99	347	8.85	148.42	995.55	68.11	812.2
1415	4006.648	8813.383	240.4	16	36	53	7.11	9.61	8190	8.83	148.42	995.55	68.02	820.12
1416	4006.648	8813.383	240.3	16	36	54	7.03	9.43	8190	8.79	148.25	995.57	67.94	822.63
1417	4006.648	8813.384	240.2	16	36	58	7.01	9.43	8190	8.57	148.76	995.51	67.74	774.77

Offline Analysis

- Python with pandas, numpy and matplotlib
- Read in data
- Get rid of invalid data
  (distance to object and valid GPS signal)
- Calibrate Temperature
- Plot the data
  (x,y-position, temperature)





Initial Test Flights

- Proof of concept test runs on a few different buildings:
  - Aerodynamics Research Buildings (ARB)
  - Farmhouse/Barn
  - Loomis Rooftop Test Trials

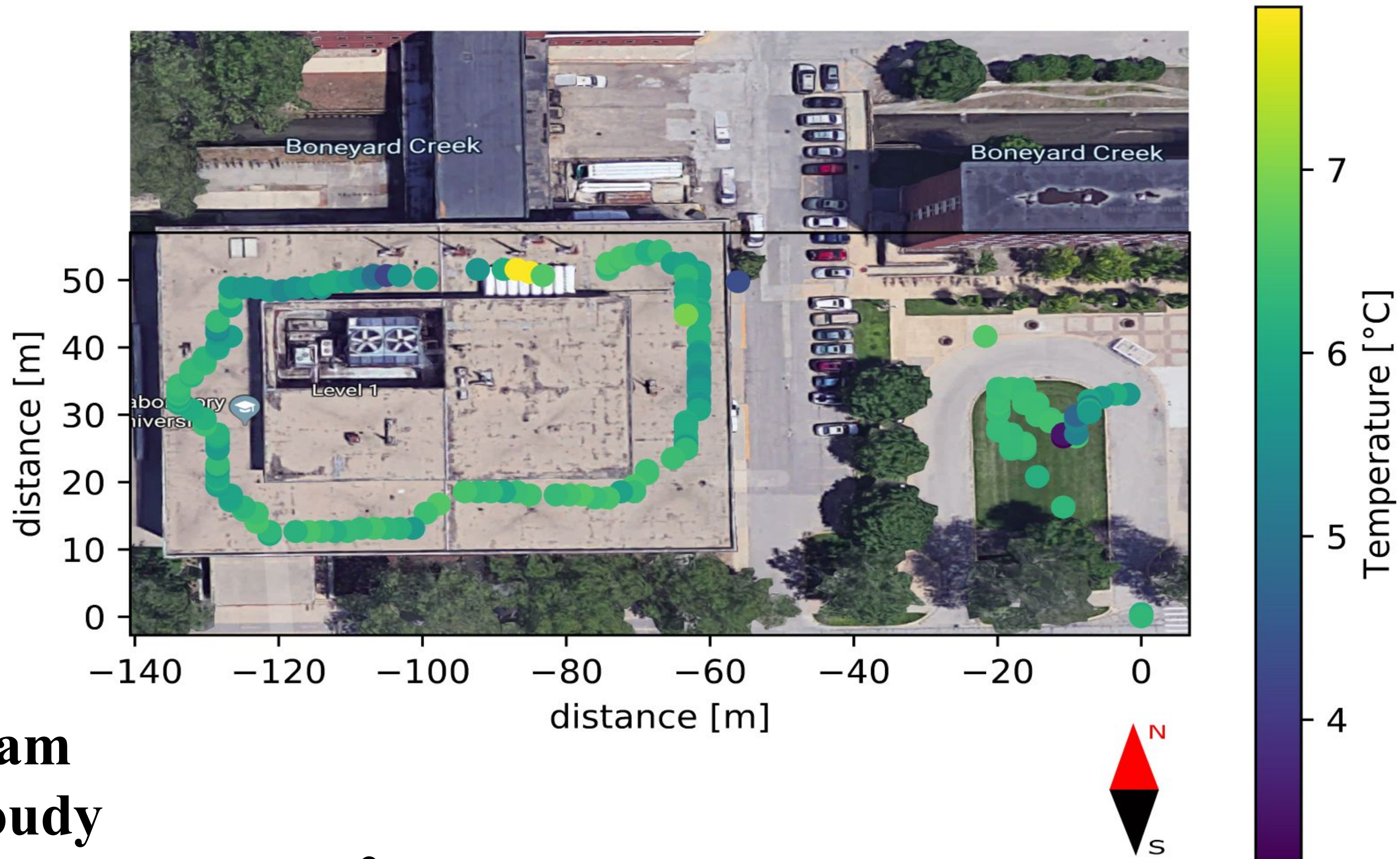
Farmhouse

ARB

Flight Plan

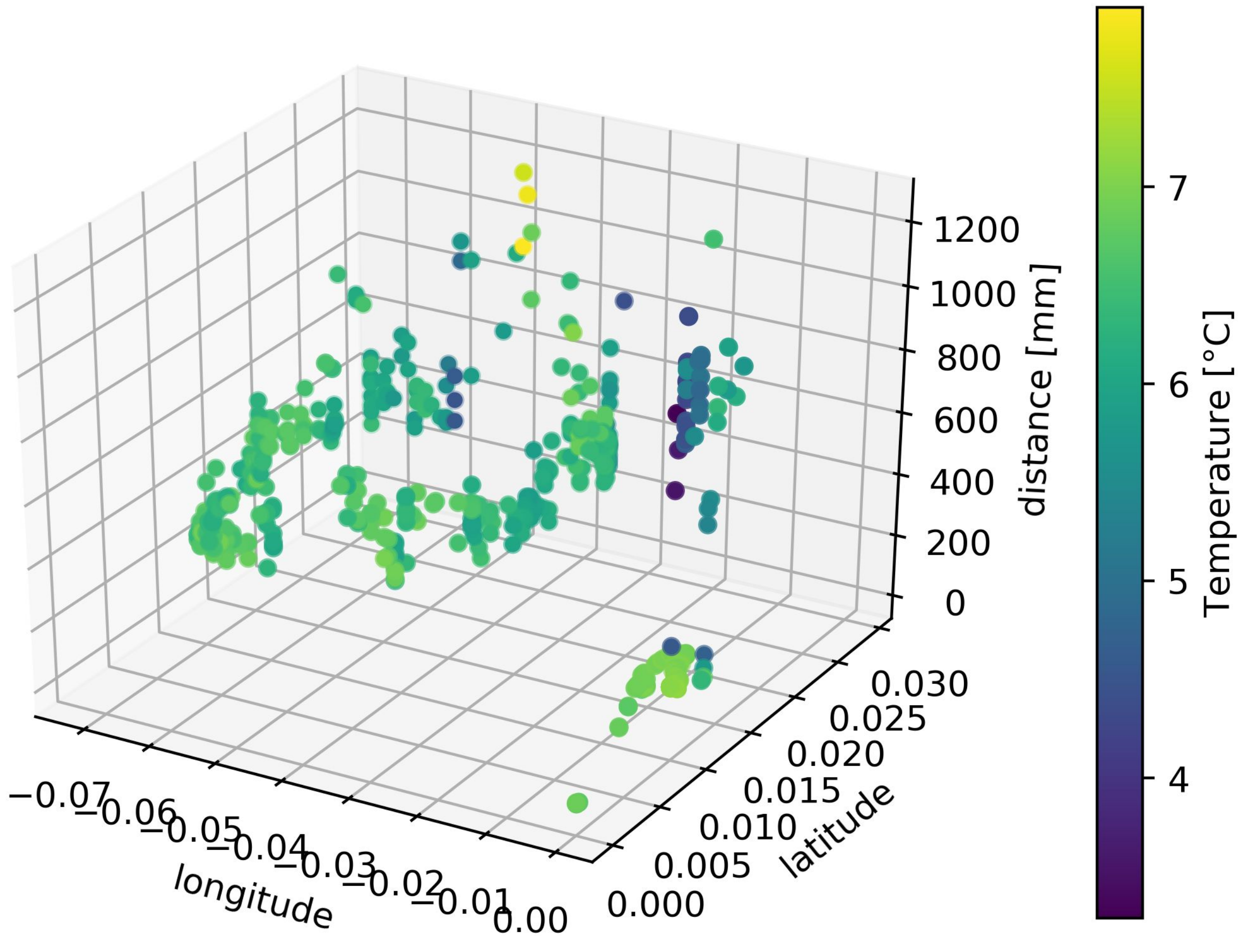
- Launched from grass pad east of Loomis
- Flown in clockwise pattern around rooftop
- Average flight time: ≅ 15 minutes
- Average sensor distance from rooftop surface: ≅ 1.5ft
- Avoided Loomis north side and due to obstacles
- Center of roof was raised and deemed unsafe to fly over due to obstacles

Results - Flight 1, Nov 18

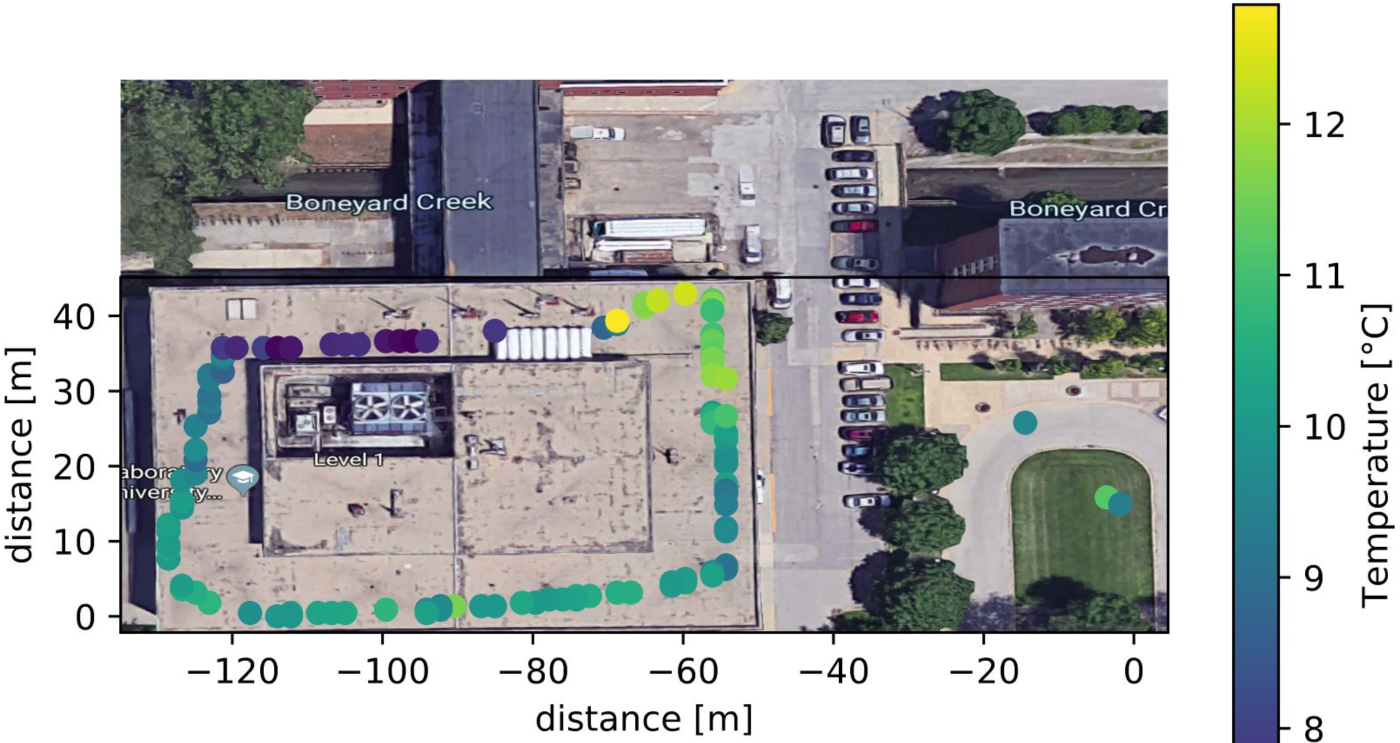


10 am
Cloudy
Ambient Temp: 5℃

Results - Flight 1, Nov 18

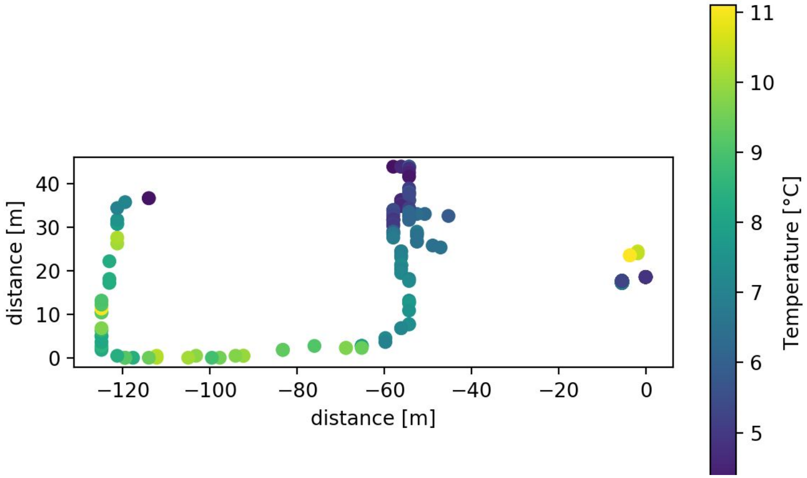


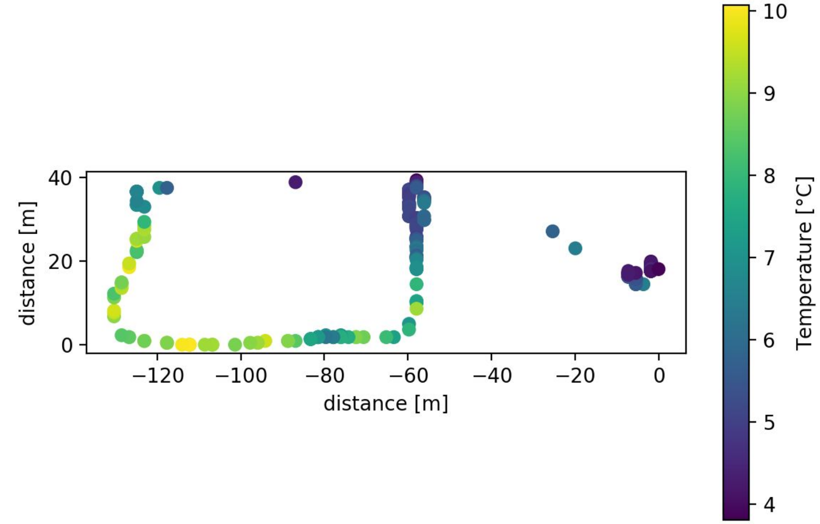
Results - Flight 2, Nov 20

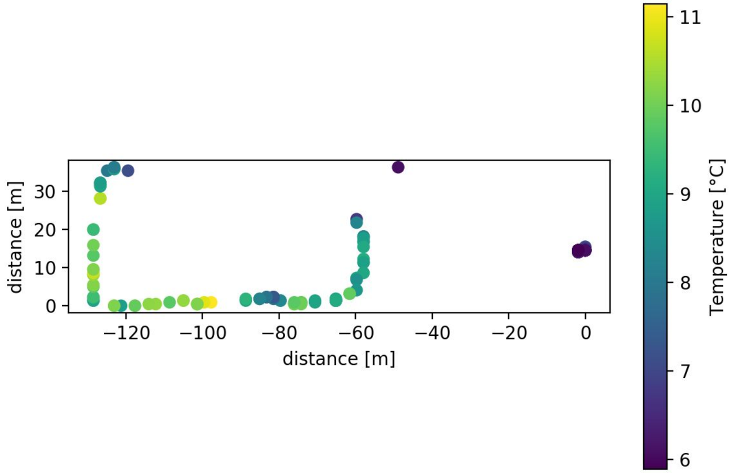


10 am
Cloudy
Ambient Temp: 5℃

Results - Flight 3,4,5 Nov 22







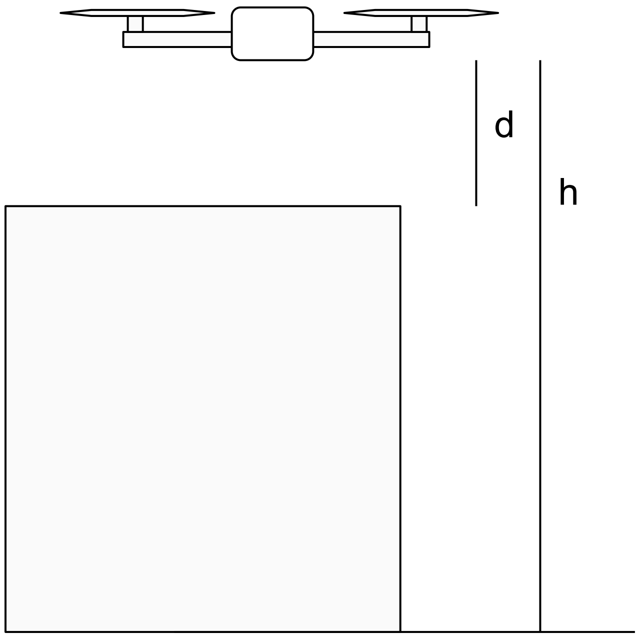
Flight time: 2:00, 2:15, 2:30 pm respectively
Sun was out, no shadows on path
Ambient Temp: 4℃

What We Found

- Each flight observed higher temperatures on south and west stretch of flight path.
- Temperature difference apparent despite clouds/shadows present or not.
- In comparison, similar cold spots were reproducible despite the weather.

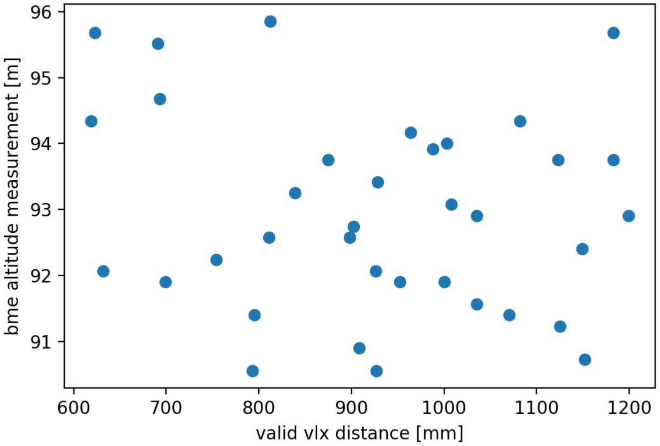
Left: east side
Right: South side

Distance-Altitude Correlation



- Idea: use BME altitude measurement for distance calculations

- No correlation between BME and VL53L0X data



Looking to the Future

- Investigating similar older buildings such as Noyes Laboratory
- AI programming to carry out flight path measurements automatically
- Additional devices could be added for more drone mounted experiments
- Drone thermal inspections on agriculture, power lines, cell towers, solar farms, etc.

Acknowledgements

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- Celia Elliott
- Todd Moore

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Any Questions?

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