Electrochemical Gas Sensors Integrated with Autonomous Aerial Vehicles for Wide Geographical Area Sensor Networks

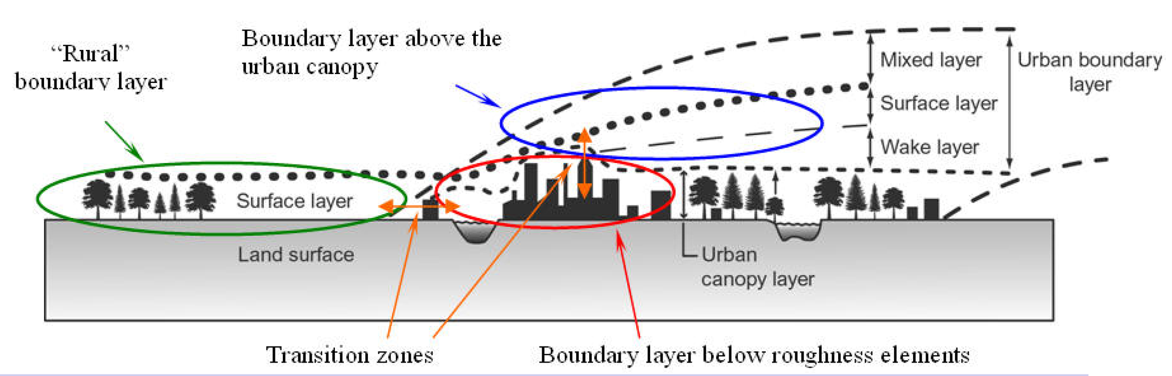
Cedric Selph [1,4], Ashish D'Souza [2,4], Dontray Dowdell [3,4], Zaki J. Harris [3,4], Caio Azevedo [3,4] and Amir Khan [3,4]

1. Dept. of Electrical Engineering, Delaware Technical Community College, Newark, Delaware
2. Polytech High School, Woodside , Delaware
3. Dept. of Physics and Engineering, Delaware State University, Dover, Delaware
4. Optical Science Center for Applied Research, Delaware State University, Dover, Delaware

Atmospheric Boundary Layer Sensing

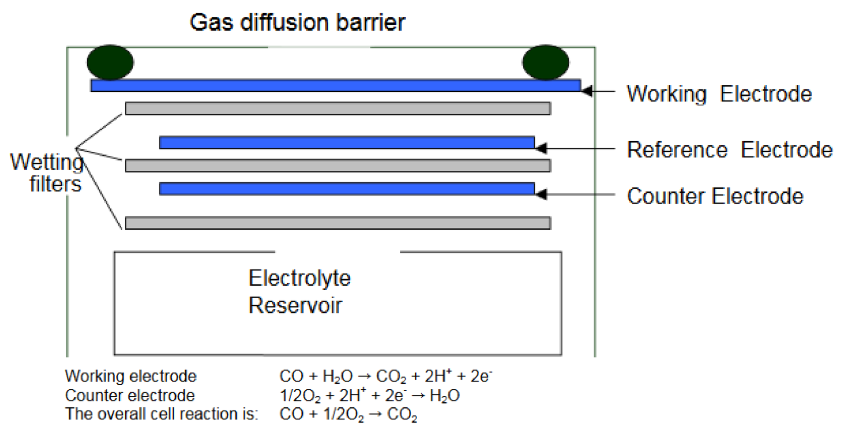
- Sensing in the ABL important to understand complicated atmospheric process in region 100 m above the earth surface.
- The required sensors are integrated to an unmanned aerial platform.

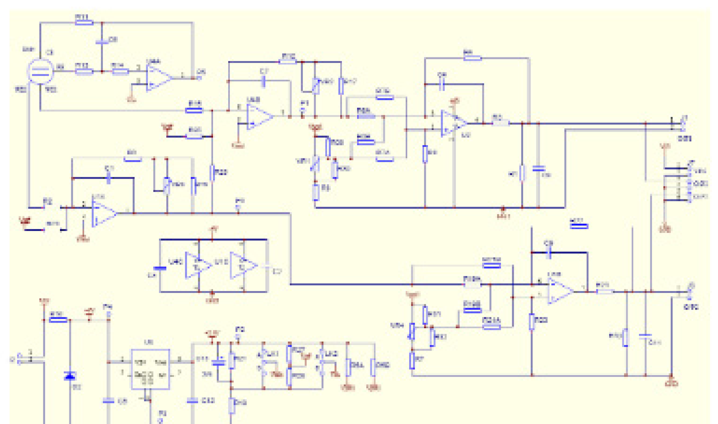
Rapid and standoff spatio-temporal profiling of toxic chemicals and pollutants in the ABL.



Alphasense EC Sensors

Working Principle: Chemicals attach to an electrode causing changes in the current/voltage.

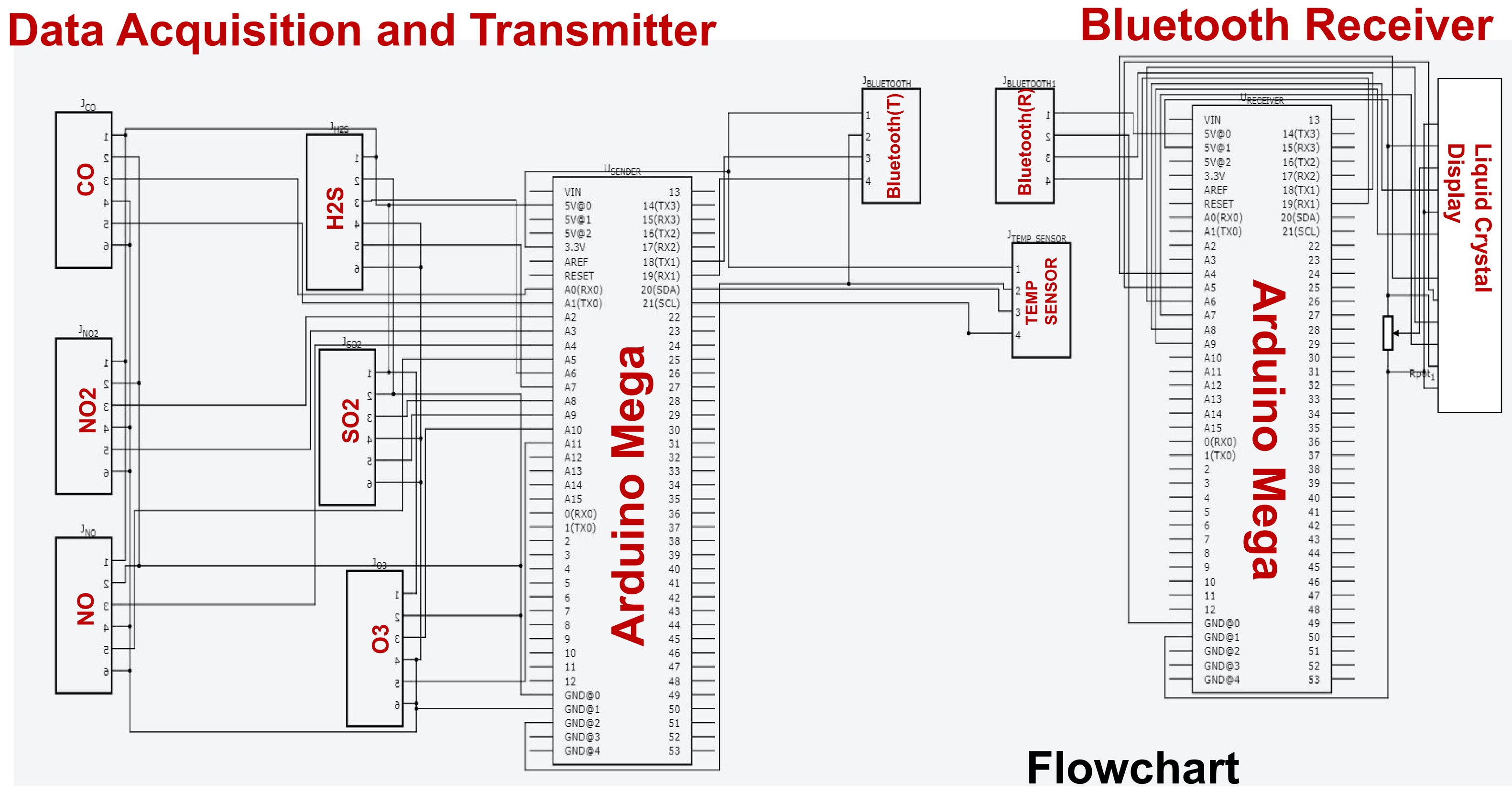




Sensor Board Schematic

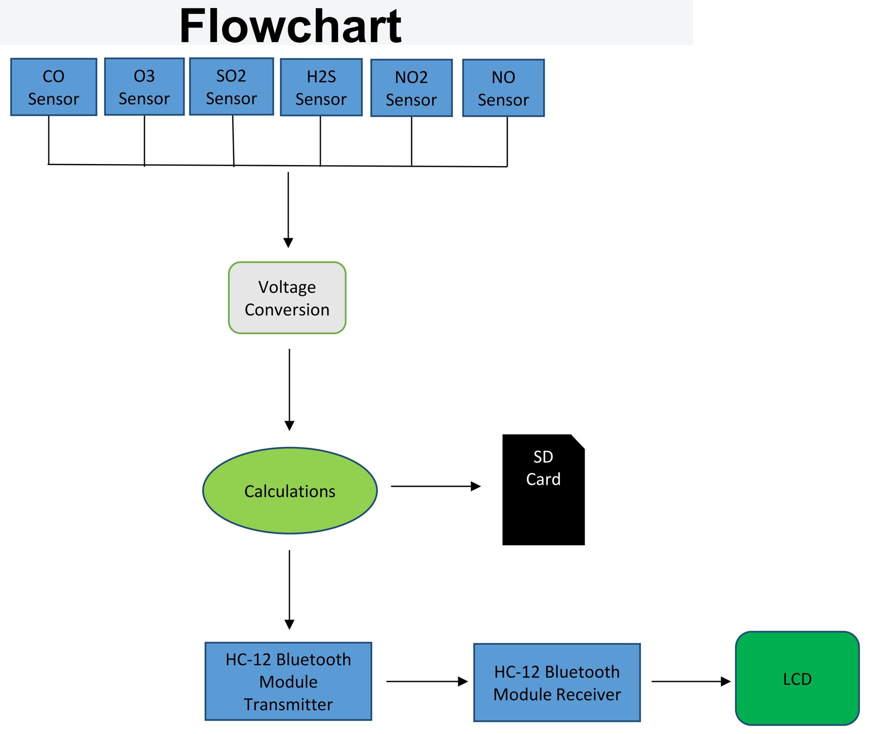
System Schematic

Data Acquisition and Transmitter **Bluetooth Receiver**

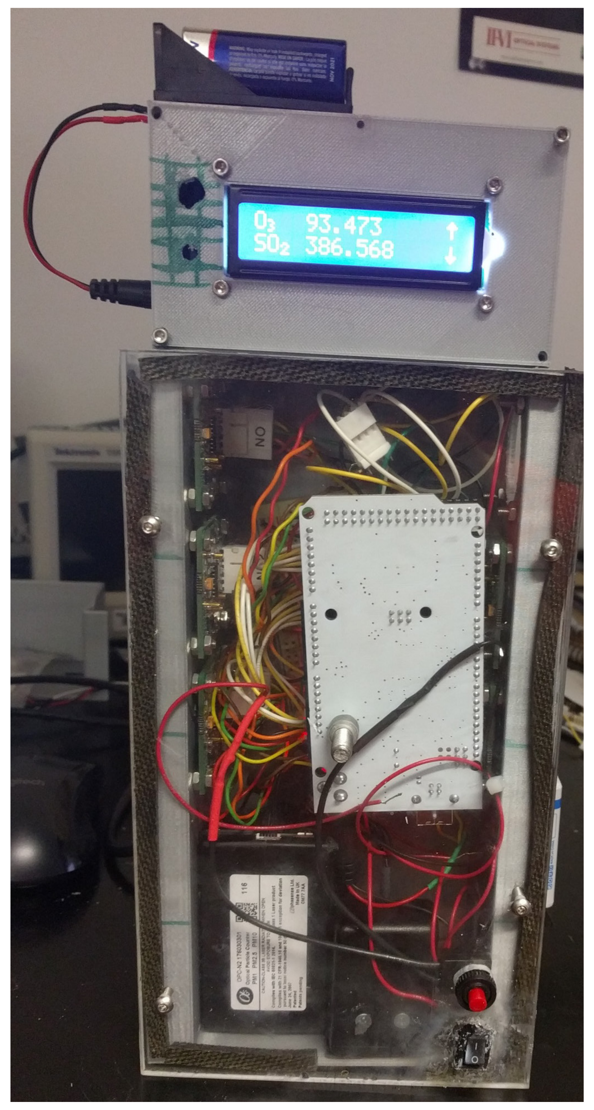


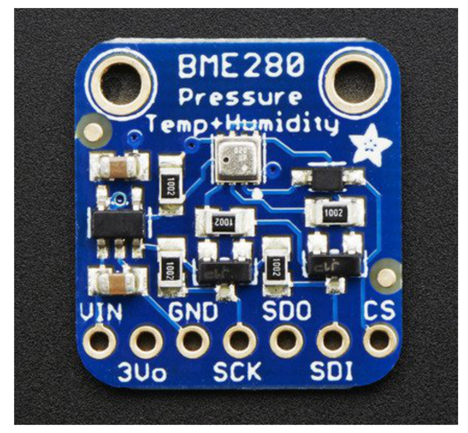

```
//Equations for WEC_RAW
float Calculate_PPB_Equation_1(float OP1_Conversion, float OP2_Conversion, float Temp_C) {

  WEC_RAW = OP1_Conversion - Temp_C * OP2_Conversion;

  return abs(WEC_RAW);
}

float Calculate_PPB_Equation_2(float OP1_Conversion, float OP2_Conversion, float Temp_C, float OP1_Zero, float OP2_Zero) {

  WEC_RAW = OP1_Conversion - Temp_C * (OP1_Zero / OP2_Zero) * OP2_Conversion;

  return abs(WEC_RAW);
}

float Calculate_PPB_Equation_3(float OP1_Conversion, float OP2_Conversion, float Temp_C, float OP1_Zero, float OP2_Zero) {

  WEC_RAW = OP1_Conversion - (OP1_Zero - OP2_Zero) - (Temp_C * OP2_Conversion);

  return abs(WEC_RAW);
}

float Calculate_PPB_Equation_4(float OP1_Conversion, float OP1_Zero, float Temp_C) {

  WEC_RAW = OP1_Conversion - OP1_Zero - Temp_C;

  return abs(WEC_RAW);

}
```

Flowchart

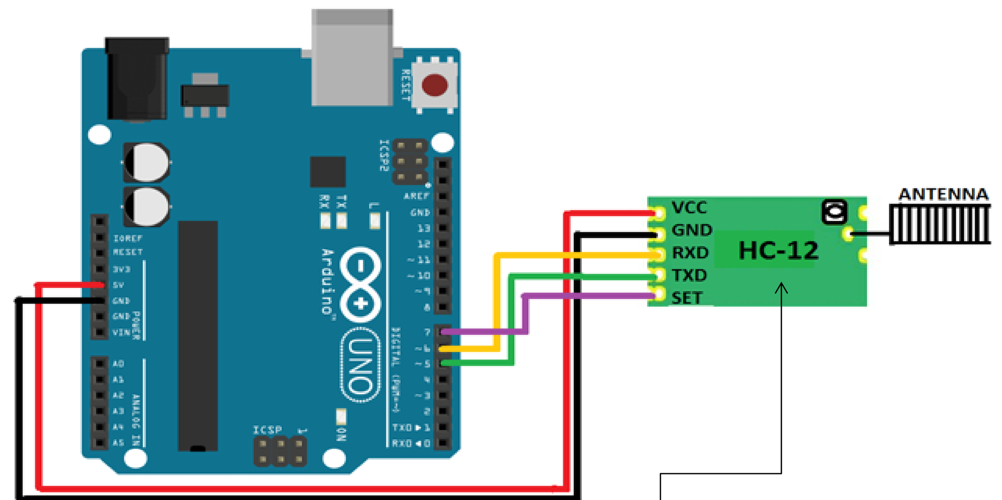


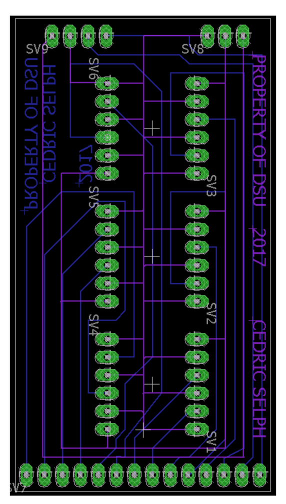
Prototype

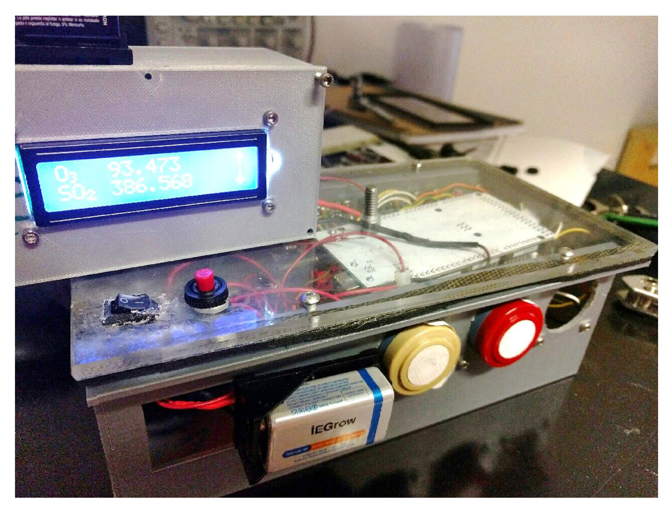




- BME 280 has a measurement range of -40 to 80 degrees Celsius.
- 1 second response time.
- 3% tolerance on measurements.







- 1.8 Km range
- Reprogrammable Baud Rates
- Half-Duplex configuration
- Full Duplex Configuration

Sensor Algorithms

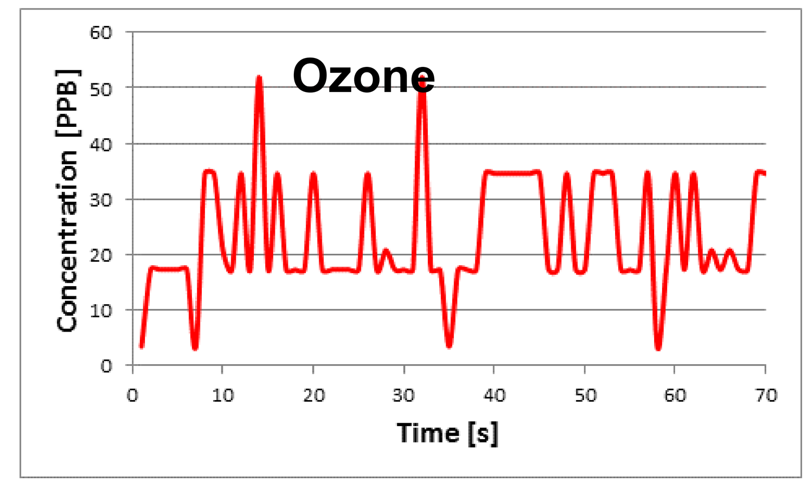
WE_c = corrected WE output
WE_u = uncorrected raw WE output
AE_u = uncorrected raw AE output
WE_o = WE sensor zero, i.e. the sensor WE output in zero air
AE_o = AE sensor zero, i.e. the sensor AE output in zero air
WE_T = Total WE zero offset
AE_T = Total AE zero offset
WE_e = WE electronic offset on the AFE or ISB
AE_e = AE electronic offset on the AFE or ISB

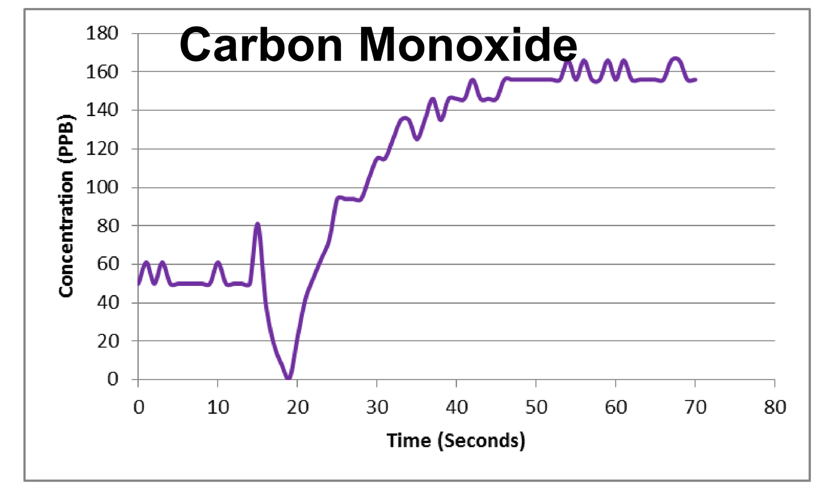
n_T = temperature dependent correction factor for algorithm 1, refer to Table 3 for values
k_T = temperature dependent correction factor for algorithm 2, refer to Table 3 for values
k'_T = temperature dependent correction factor for algorithm 3, refer to Table 3 for values
k''_T = temperature dependent correction factor for algorithm 4, refer to Table 3 for values

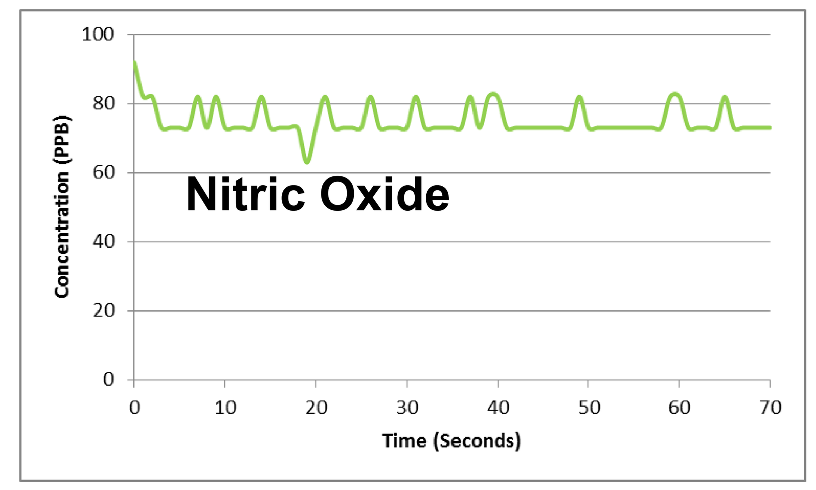
Algorithm	Equation	Notes
1	$WE_c = WE_u - n_T * AE_u$	Directly scales the AE output. Gross under or over compensation can occur if AE_u is of opposite sign to n_T, or AE_u is significantly smaller or larger than WE_u.
2	$WE_c = WE_u - k_T * \left(\frac{WE_o}{AE_o}\right) * AE_u$	Scales AE by using the individual sensor calibration data. Gross under or over compensation will result If AE is very small or zero, or If WE_{cal} and AE_{cal} are of opposite signs, or the AE_T output is significantly smaller or larger than the WE_T output.
3	$WE_c = WE_u - (WE_o - AE_o) - k'_T AE_u$	Avoids the problem of Algorithm 2 with a zero AE_o value. Gross over or under compensation can result if AE_o is of opposite sign to WE_o, or if AE_o is significantly smaller or larger than WE_o.
4	$WE_c = WE_u - WE_o - k''_T$	Correction wihout using the AE_o result. Gross under or over compensation can occur if AE_u is significantly smaller or larger than WE_u.

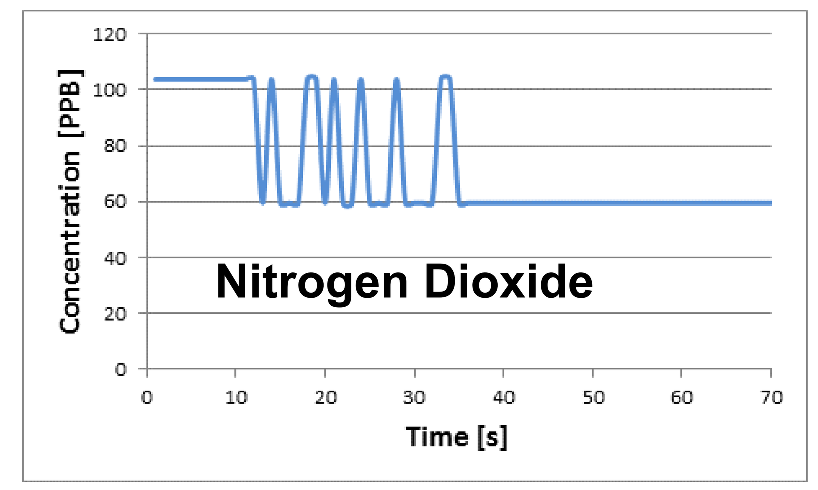
Measurements of Air Quality

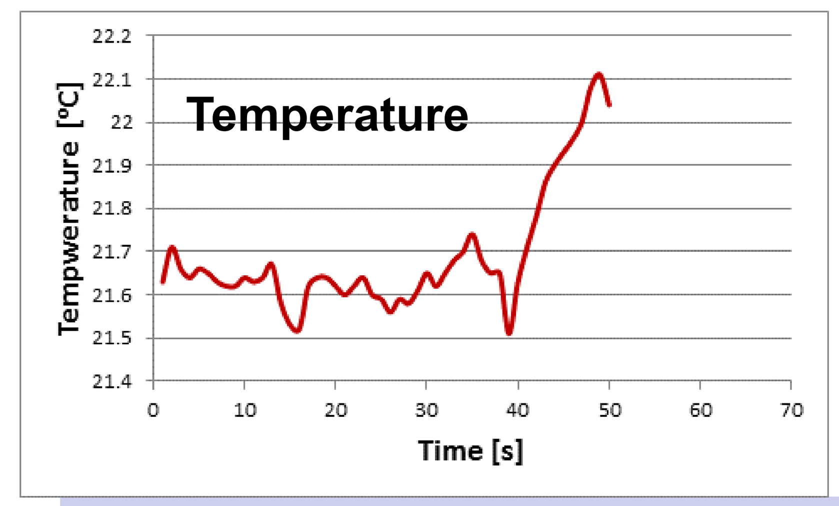
- 1- sec. sampling rate with concentration ranges in Parts Per Billion(PPB) over a 70 second interval.

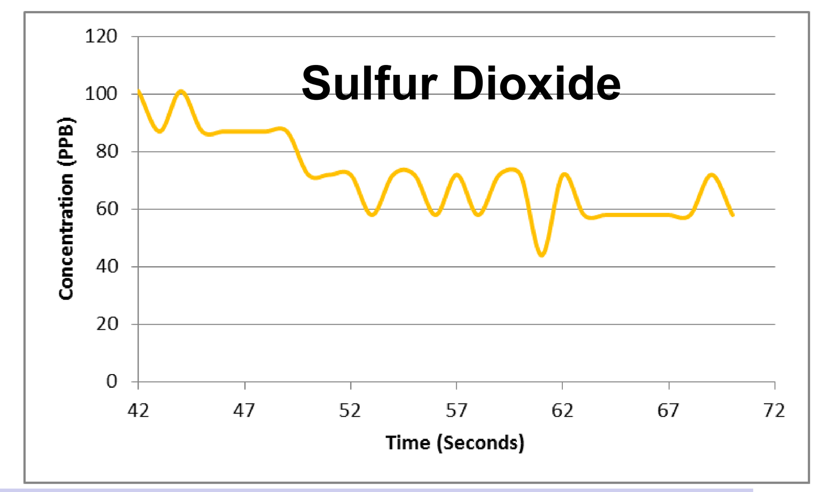












Conclusion and Future Work

Future integration with a DJI Phantom Aerial System for short term Aerial profiling over a wireless sensor network.

- The prototype was successful y implemented in laboratory tests, future work incudes ABL sensing with low- payload Ariel vehicles.
- System can be further miniaturized, and computational algorithms, data communications can be further optimized for delays and real-time data synchronization with field sensors.
- Additional greenhouse gas sensors example carbon dioxide and methane sensors will be integrated to the current module.

We acknowledge the Optical Science Center for Applied Research (OSCAR), the financial support of The National Science Foundation (NSF-CREST grant Nº 1242067 and of the National Aeronautics and Space Administration (NASA URC 5 grant Nº NNX15AP84A).