Linking Microclimate and Energy Use with a Low Cost Wall Mounted Measurement System

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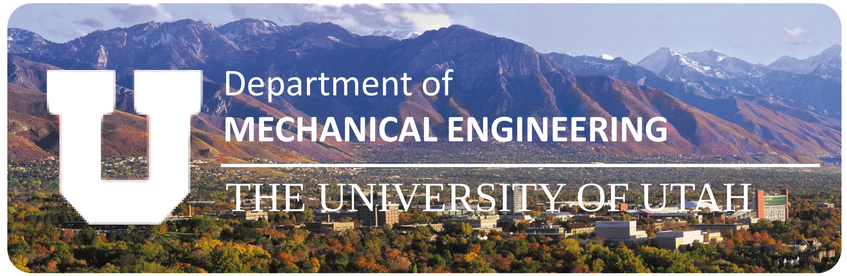


Abstract

Urban microclimate plays a critical role in overall urban energy demand and efficiency. At the building scale, energy use and internal conditions are directly impacted by local microclimate. The direct link between building energy use and local microclimate is through building envelope heat fluxes. The Building Temperature Energy Monitoring System (B-TEMS) project was created as a low cost solution to investigate these heat fluxes through the walls of commercial buildings. This poster describes the design and assembly of Arduino microcontroller-based temperature and humidity sensors called B-TEMS, which record ambient air temperature, wall surface temperature, and relative humidity for both internal and external environments. These systems are used to quantify energy losses through two walls in a building at the University of Utah. The B-TEMS are deployed by attaching them to the inside and outside of exterior walls and windows. Ambient air temperature and humidity were measured via a Sensirion SHT 21 sensor while wall surface temperature was measured by a Melexis MLX 90614 infrared temperature sensor. Data were collected on an SD card every 30 seconds using an Arduino Pro Mini for several hours. Results from the experimental analysis are used to compare results for predicted temperatures using the methods in EnergyPlus[1], a commonly used open-source building energy modeling software. Measured differences between local experimental results and modeled results from EnergyPlus will help researchers evaluate the effects of including microclimate data on model accuracy. This system provides a low cost, simple solution to monitor microclimate and wall energy fluxes together, leading toward more accurate building energy simulations.

Project Objective

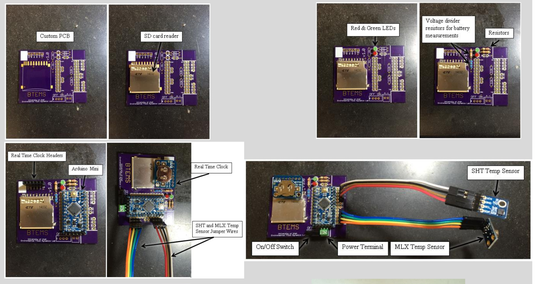
The Building Temperature Energy Monitoring Systems project seeks to experimentally quantify energy gains and losses through the building envelope in the form of heat. This information shall be used to investigate effects of local microclimate conditions on building energy performance and evaluate the impact that including microclimate data in building modeling software, such as EnergyPlus, will have on the software's accuracy.

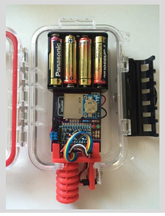
Design Objectives

1. Sensors must record accurate ambient air temperature.
2. Sensors must record accurate wall/window surface temperature
3. Sensors must record accurate atmospheric relative humidity
4. Sensors must perform in both interior and exterior environments
5. Sensors must reliably store data internally until data collection can be performed
6. Sensor battery life must be reliable for a minimum of one month without maintenance
7. (Optional) PCB may have one extra port for additional sensor placement should the experimental design change in the future

BTEMS Physical Design & Assembly

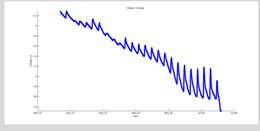
- Microprocessor: Arduino Pro Mini
- Ambient Temperature & Relative Humidity: Sensirion SHT 21 (± 0.5 ºC [2])
- Infrared Surface Temperature: Melexis MLX90614 (± 0.5 ºC [3])
- Power: AA Batteries (x8, ~1.5-2 months worth of battery life)
- Shield Board: Custom designed by the U of U fluids department
- Radiation Shield: Custom 3D printed design from the U of U ME department
- Data Storage: SD or MicroSD card
- Data Collection: Manual collection by students
- Cost: ~$70 - $80 per unit





Challenges

- Battery packs began with 4 AA per unit. The life of the battery was found to be reduced in exterior units that are exposed to direct sunlight. (See battery figure to the right)
- Temp plots indicate some sensors may not be receiving adequate aspiration through the radiation shield. Further testing is underway to verify this.



Above: Battery profile for the exterior BTEMS on the East wall. The pack of 4 AA batteries lost power after 3 weeks use. Strong diurnal fluctuations can be seen in the battery voltage which led to the decision to use packs of 8 batteries instead of 4.

Experimental Setup & Deployment

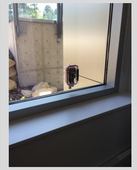
The Kennecott Mechanical Engineering building at the University of Utah was chosen as the first building for BTEMS deployment. Eight BTEMS were constructed for this first round allowing two (one interior and one exterior) to be deployed in each cardinal direction. The experimental objective is to accurately measure heat fluxes through the building envelope. This data, along with building utility data, will later be used to quantify energy gains and losses due to local microclimate conditions.

Estimating heat gains/losses: $q = \frac{A*\Delta T}{R_{tot}} = UA(T_o - T_i)$ [4]

Where: q = heat transfer; A = wall surface area; R = wall thermal resistance

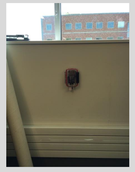
North wall interior

North wall exterior

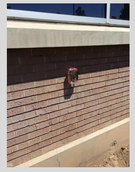


East wall interior

East wall exterior

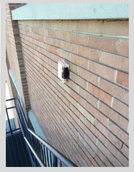


South wall interior



South wall exterior

West wall interior



West wall exterior

*All BTEMS were adhered to the wall using 3M Velcro strips

Summary Points

- BTEMS provided a low cost atmospheric measurement device allowing us to collect the needed data without expensive or unnecessary equipment
- The data produced by the BTEMS thus far follow what would be expected in the deployment locations they are found and are in the process of being verified
- Advancement of the project to the next phase of monitoring multiple buildings and comparison with EnergyPlus results is ready pending verification tests in progress

Acknowledgements

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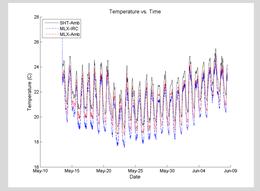
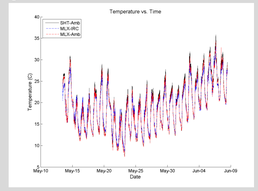
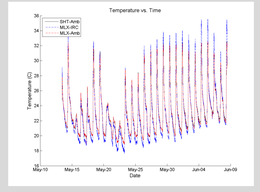
Preliminary Results



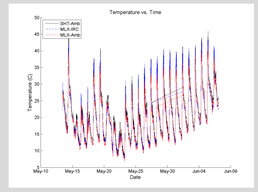
North wall interior



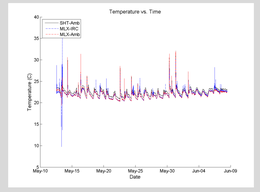
North wall exterior



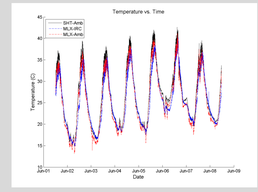
East wall interior



East wall exterior



South wall interior



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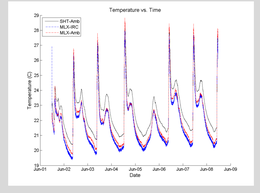
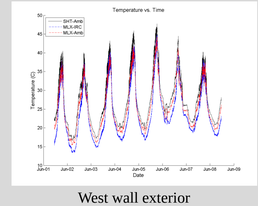


West wall interior



West wall exterior

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