Hybrid Experimental-Numerical Approach to Solve Inverse Convection Problems

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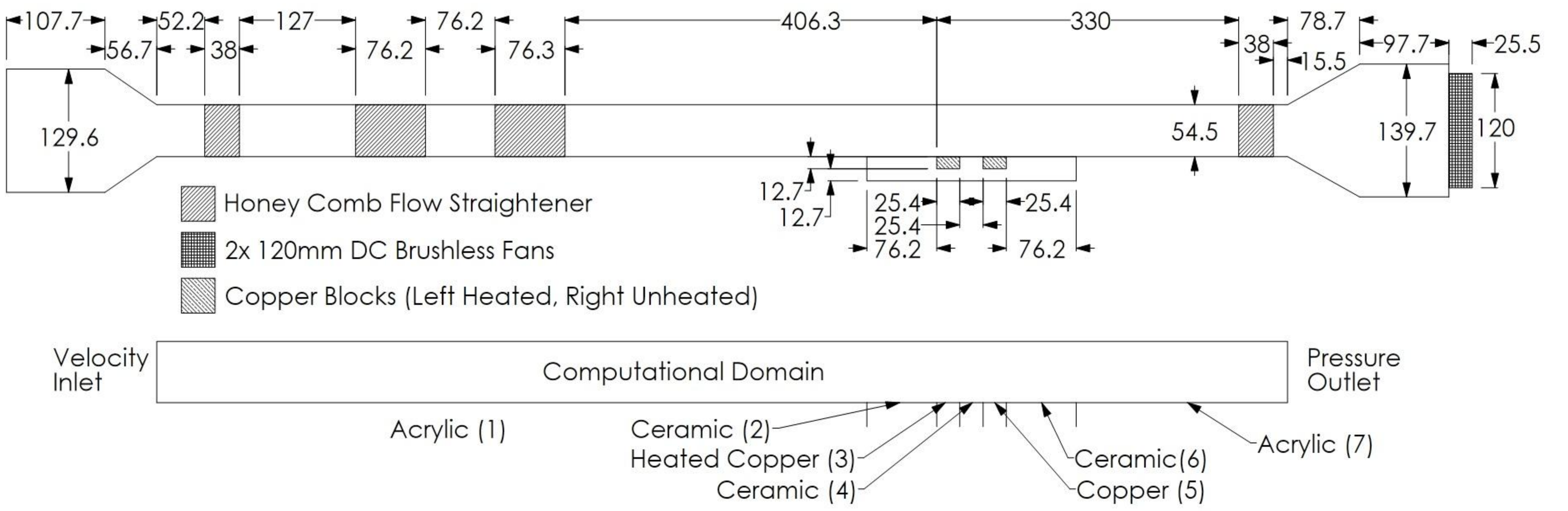
Introduction

A combined experimental and numerical study was performed to determine the plausibility and effectiveness of a method to solve inverse convection problems.

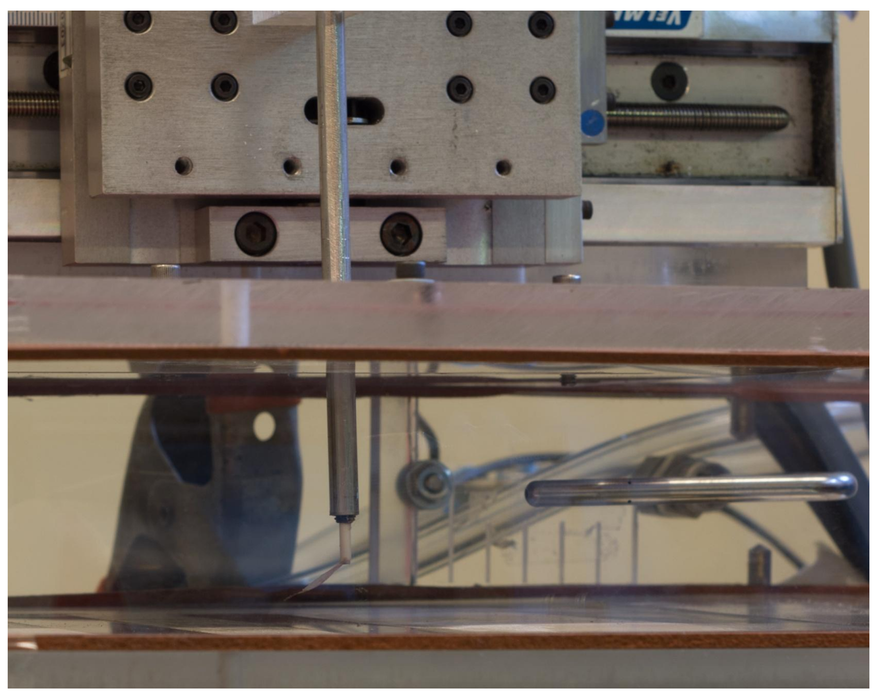
A plume in a crosswind was selected due to its relative simplicity and wide range of applications.

The goal was to predict both plume location and temperature.

Experimental Layout and Simulation Domain

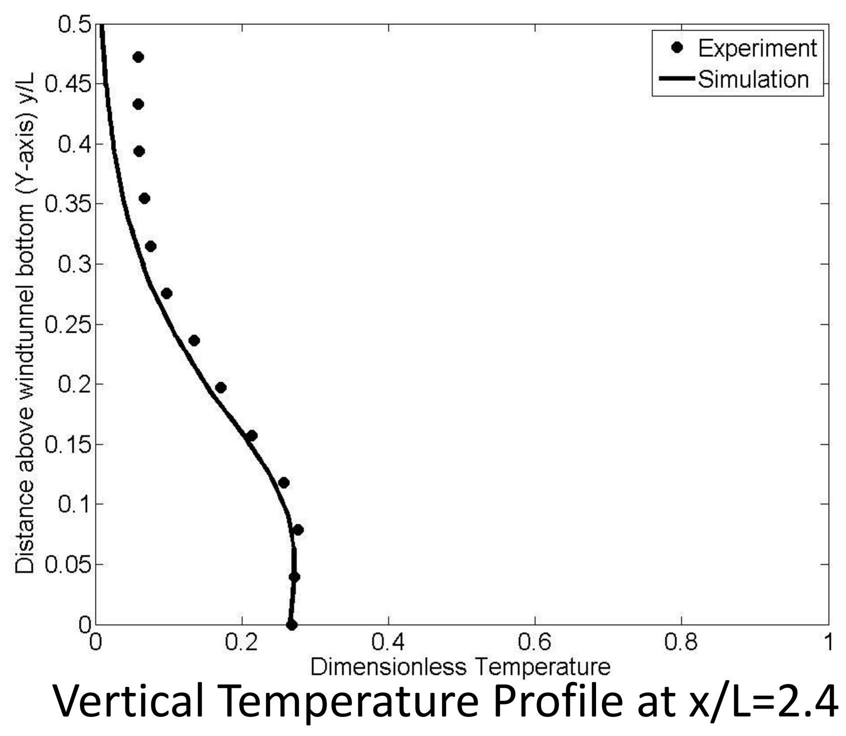


Experimental Test Section Close-Up

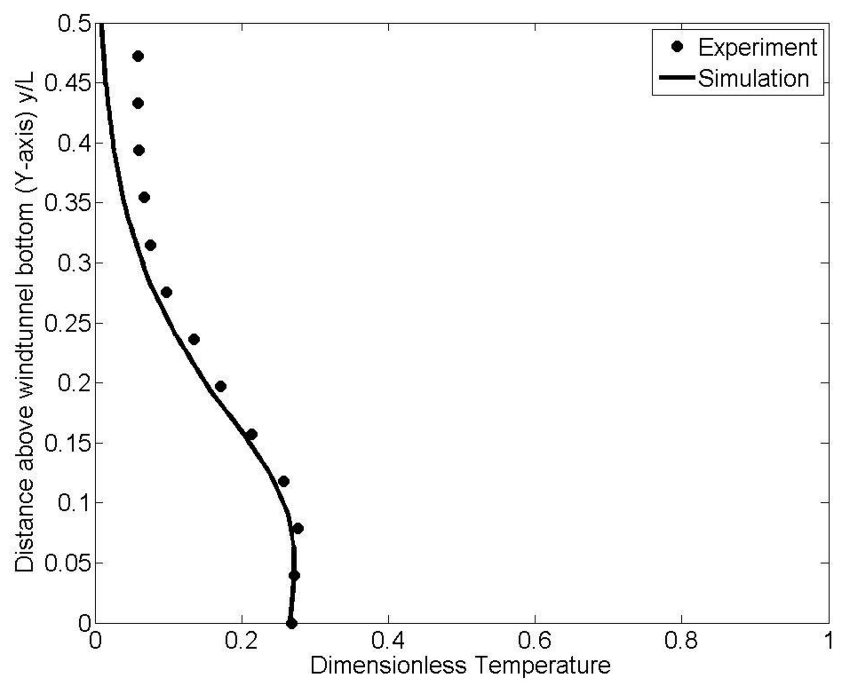


Experiment – Simulation Agreement

Vertical Temperature Profile at x/L=1.6



Vertical Temperature Profile at x/L=2.4



L is the width of the heated section 25.4mm

Objective Function

First Stage (Predict Source Temperature)

$$F(x,y)=\sum_{i=2}^{n}\left[m(x+\Delta x_i, y+\Delta y_i)T(x_i,y_i)+b(x+\Delta x_i, y+\Delta y_i)-m(x,y)T(x_1,y_1)-b(x,y)\right]^2$$

$$T_{SP}=\frac{\sum_{i=1}^{n}\left[m(x^*_{SP}+\Delta x_i, y^*_{SP}+\Delta y_i)T(x_i,y_i)+b(x^*_{SP}+\Delta x_i, y^*_{SP}+\Delta y_i)\right]}{n}$$

Second Stage (Predict Source Location)

$$F_{\mathrm{mod}}(x,y)=\sum_{i=1}^{n}\left[m(x+\Delta x_i, y+\Delta y_i)T(x_i,y_i)+b(x+\Delta x_i, y+\Delta y_i)-T_{SP}\right]^2$$

$$T_S=m(x,y)T(x,y)+b(x,y)$$

$$m(x,y)=\frac{T_{SA}-T_{SB}}{T_A(x,y)-T_B(x,y)}$$

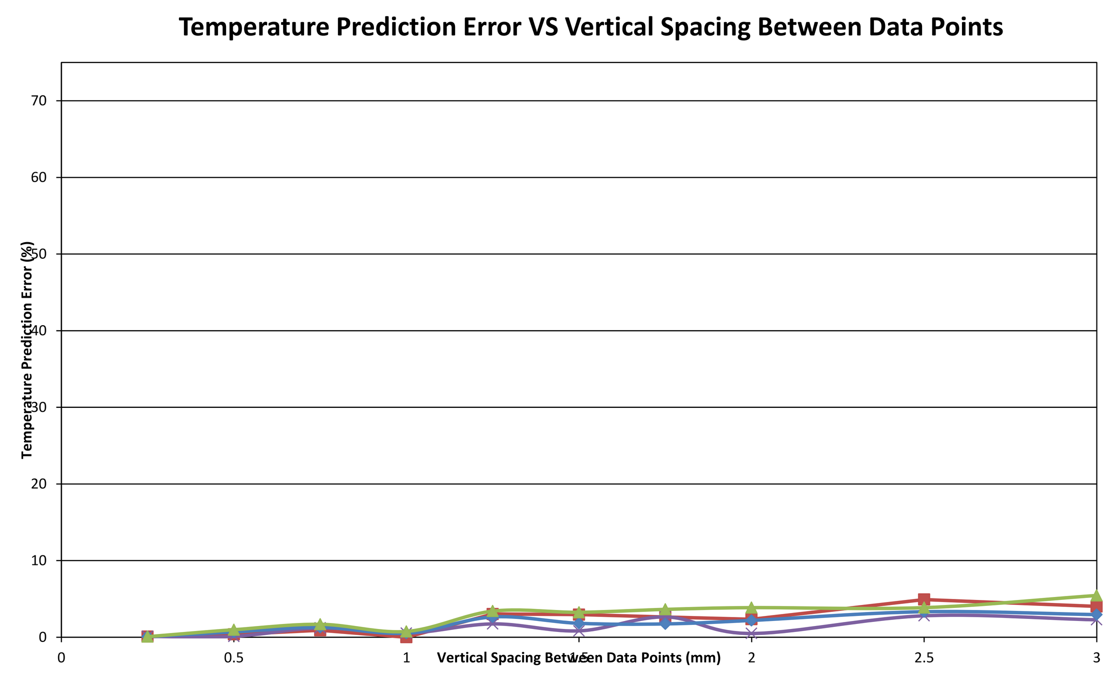
$$b(x,y)=T_{SA}-m(x,y)T_A(x,y)$$

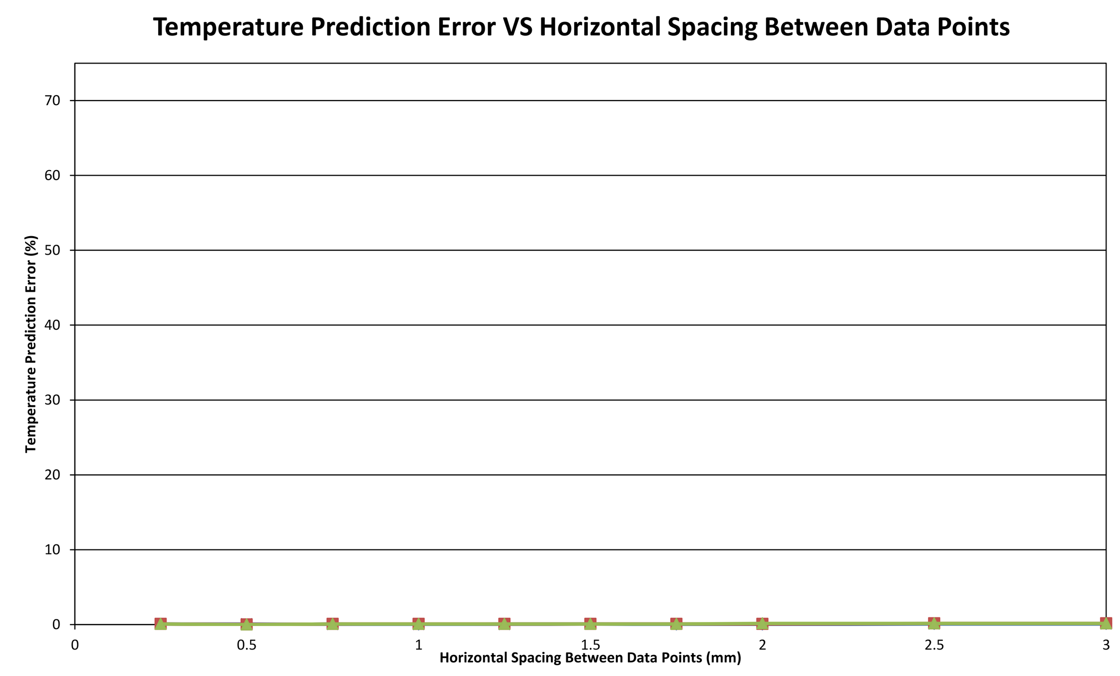
$$x_i=x_1+\Delta x_i$$

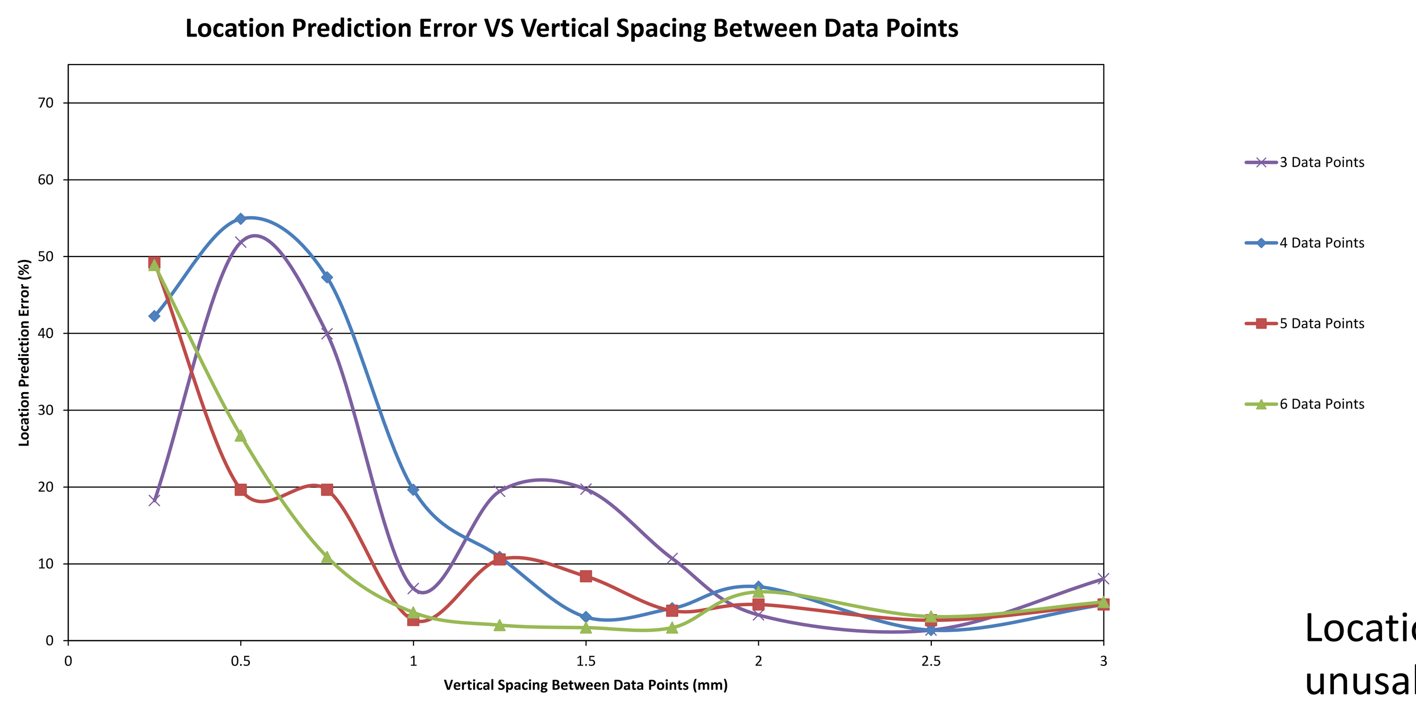
$$y_i=y_1+\Delta y_i$$

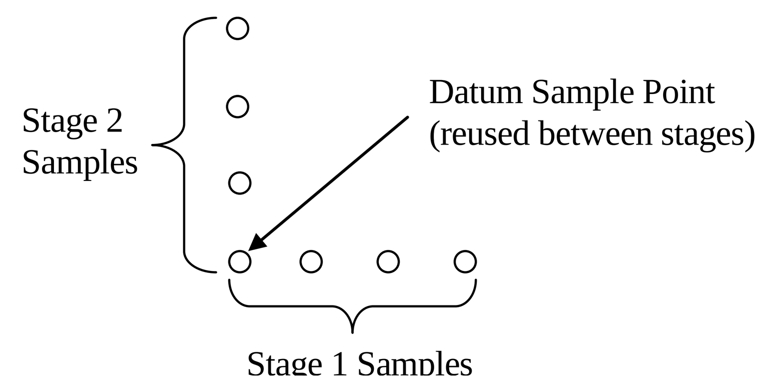
x^*_{SP}, y^*_{SP} coorespond to the minimum of F

Sampling Pattern



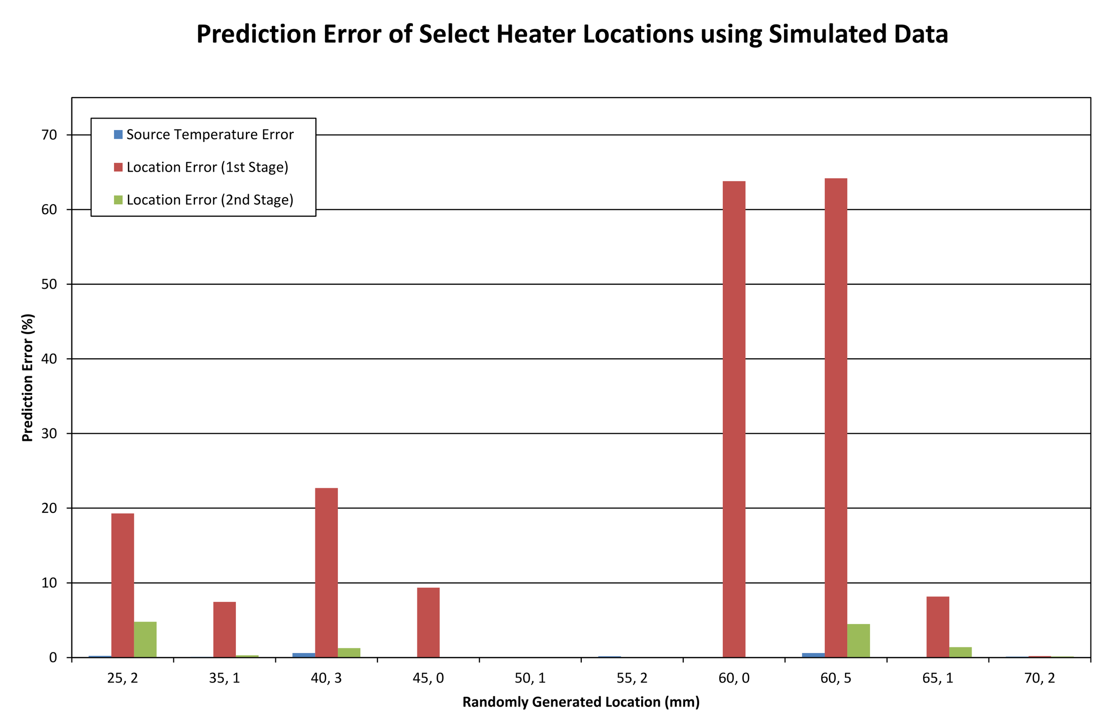


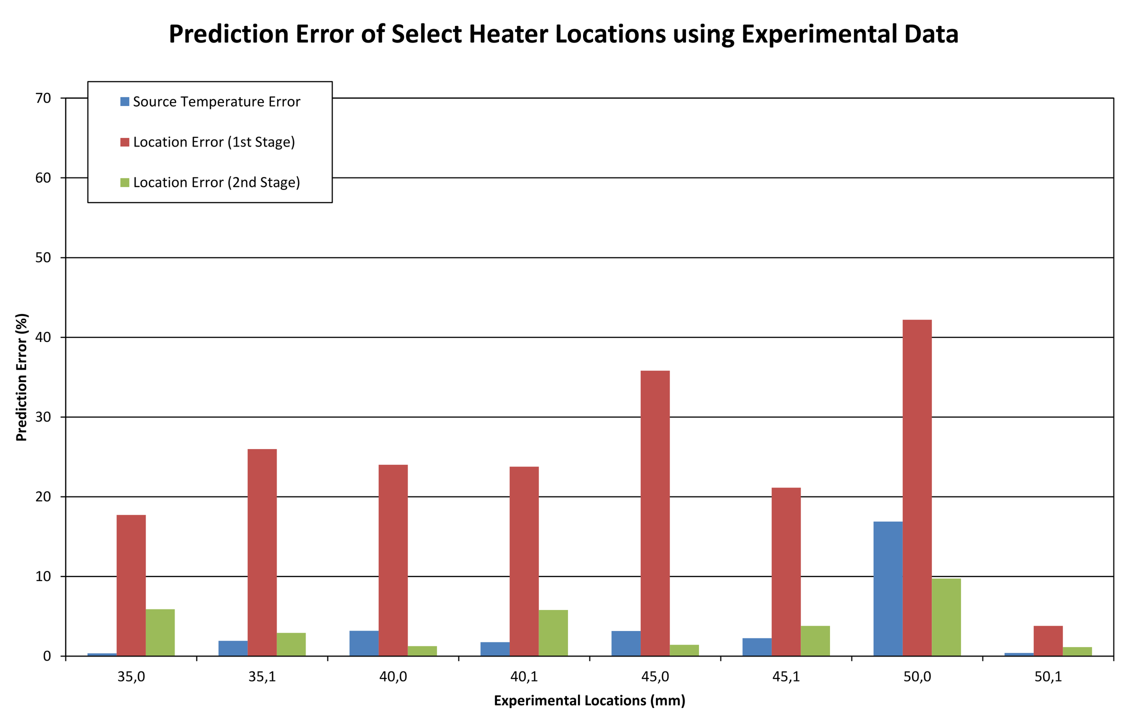




Location Prediction Error vs Horizontal Spacing has unusable coorelations.

Results





Conclusions

- Algorithm tests show less than 1% temperature prediction error is possible and 5% for location prediction error
- Experimental tests show 3% and 6% for temperature prediction error and location prediction error respectively
- The methodology demonstrates robust potential