# Heat Transfer Modeling of Large Shipping Containers
## (Project Updates)

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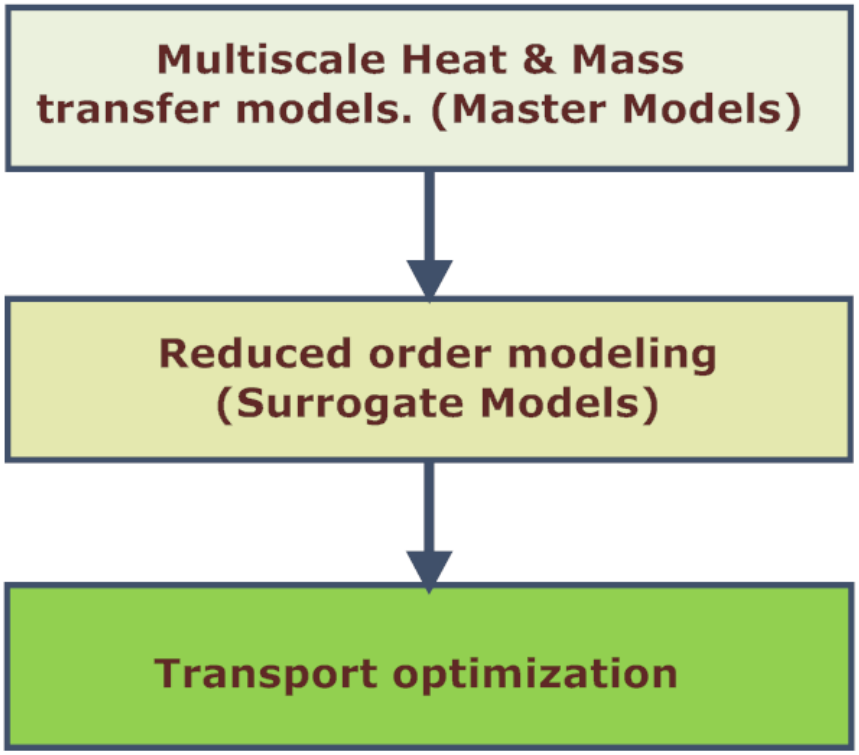
## Motivation

- Predict the temperature impact on the product shelf-life during transportation.
- Optimize transportation to reduce the impact of temperature on shelf-life.

## Project framework

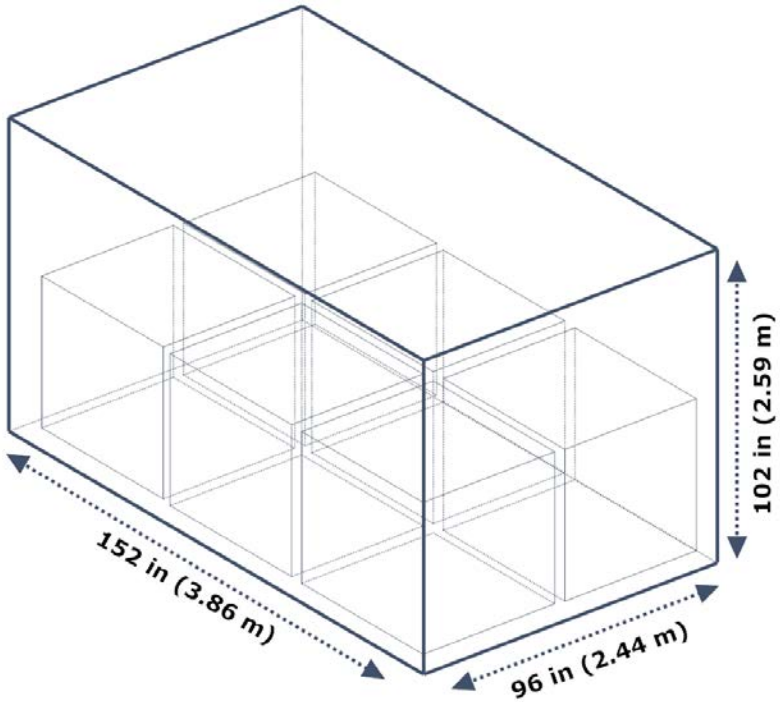


**Project updates:**

- completed two 2D CFD model for a container with a capacity of 6 pallets.
- completed a 3D CFD model for the same container.
- compared and tuned the models against experimental data
- build a parallelized Matlab code that enabled the simulation of multiple weather scenarios in the same time.
- tested the models for different weather scenarios at different locations on the globe: *Chennai India, Chino CA USA, Cincinnati OH, USA , Durban South Africa, Guangzhou China, Jeddah Saudi Arabia, Rio de Janeiro Brazil*
- completed a 2D and a 3D CFD model for a 40 ft semitrailer with a considered capacity of 24 pallets
- started working on building reduced order models of the CFD models.

## Fairfield OH - Experiment

- 152 /96/102 in Container aligned to the North
- 6 pallets
- 210 – 1 gallon bottles of water/pallet
- Temperature was recorded at a
  10 min interval for a period of 30 days

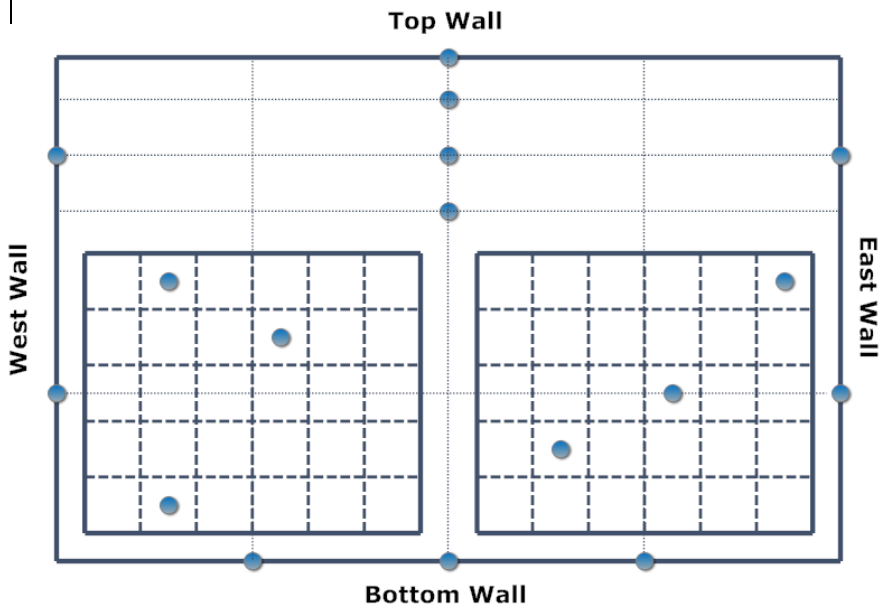


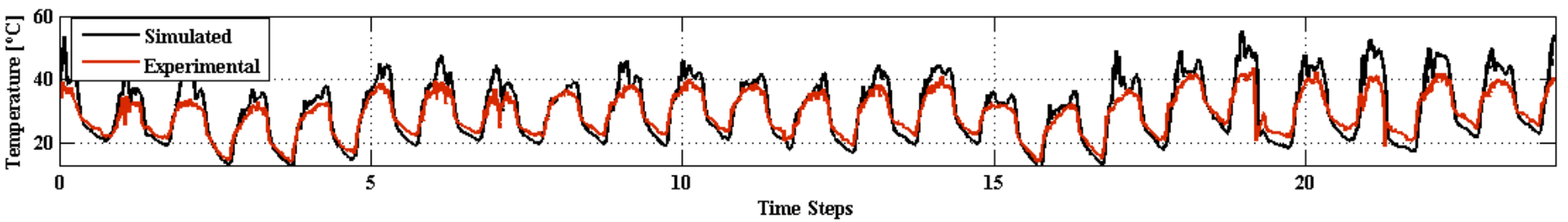

## Mathematical modeling

3 CFD models were build:
One 3D model – 3375 mesh elements
Two 2D models – 135 and 225 mesh elements

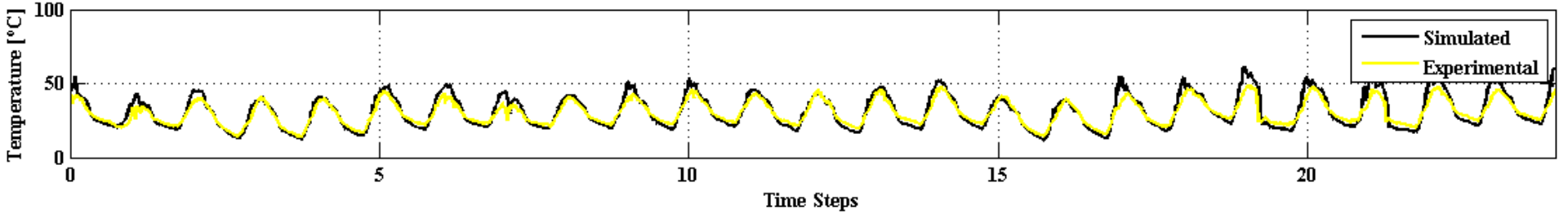
Homogenous pallets:

- 0.4060 conductivity [W/mK]
- 698.60 density [kg/m$^3$]
- 2926.00 specific heat [J/Kg K]

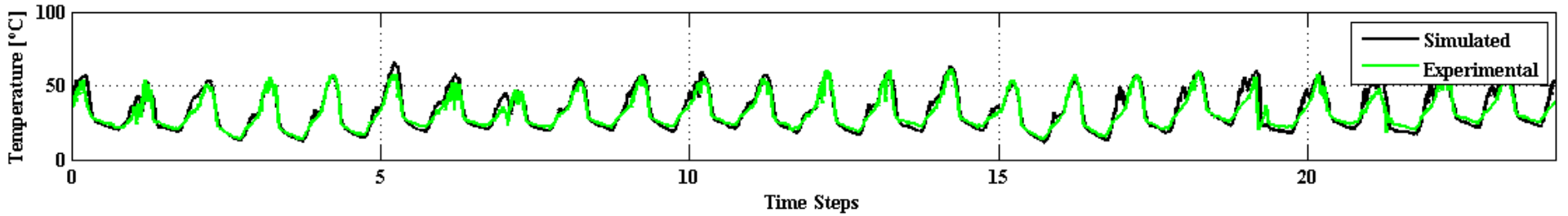




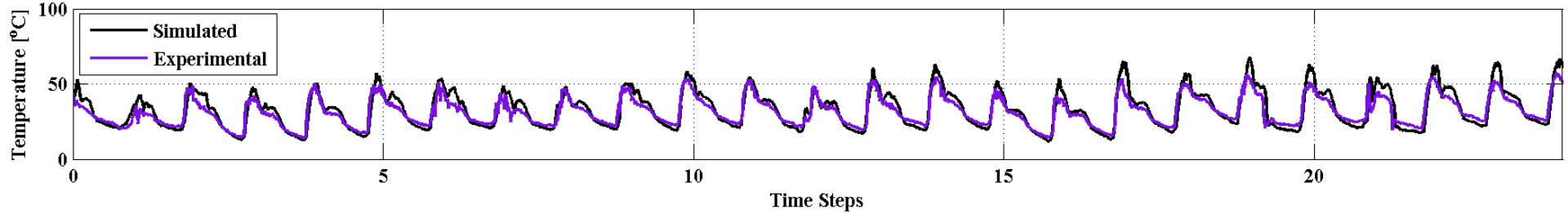

Temperature variation on the North Wall of the container.



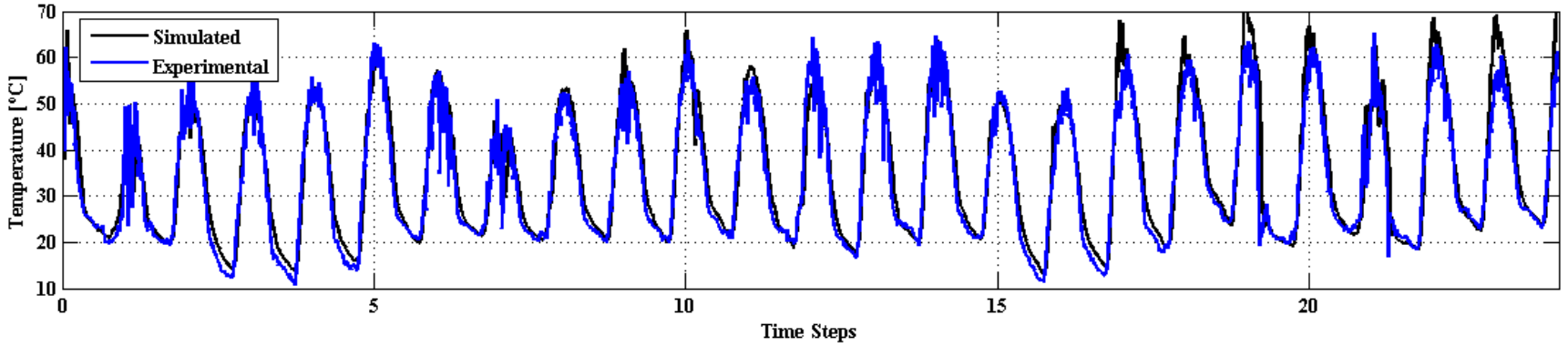

Temperature variation on the West Wall of the container.



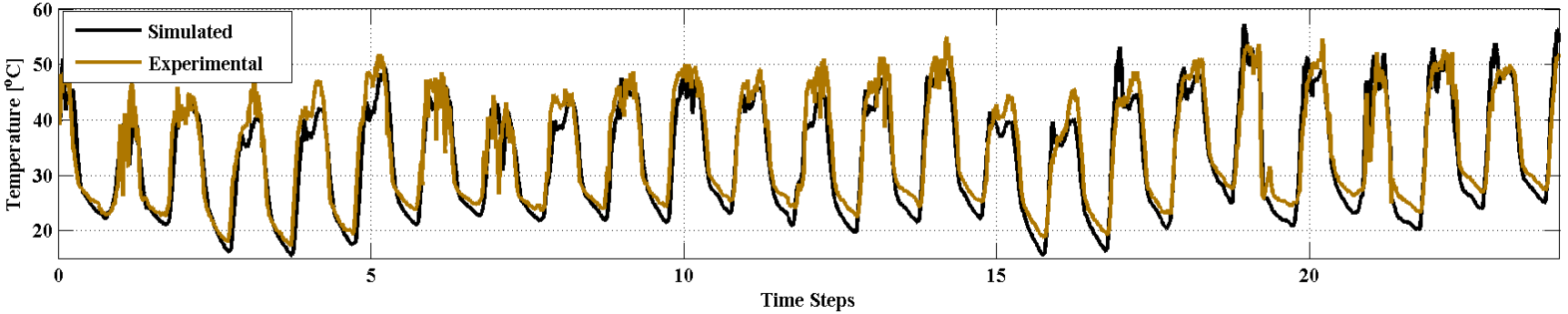

Temperature variation on the East Wall of the container.



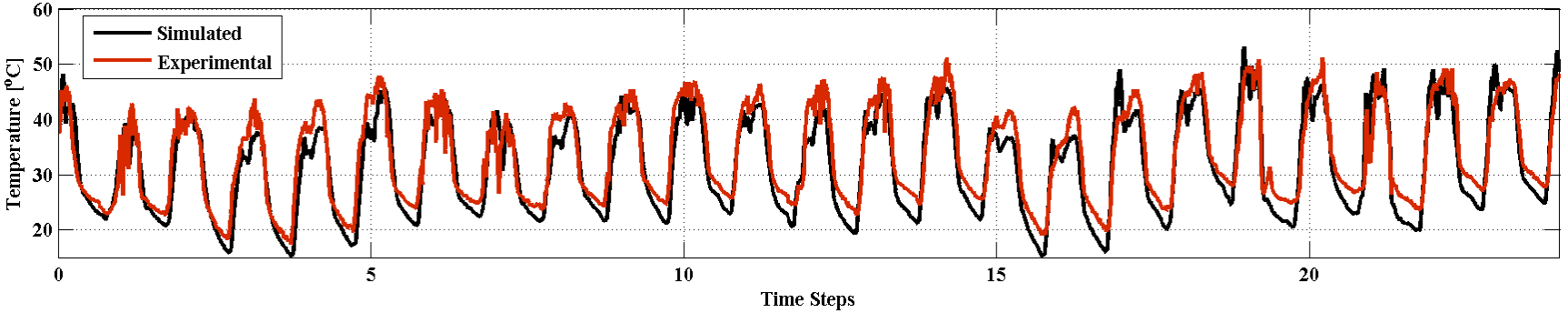

Temperature variation on the South Wall of the container.



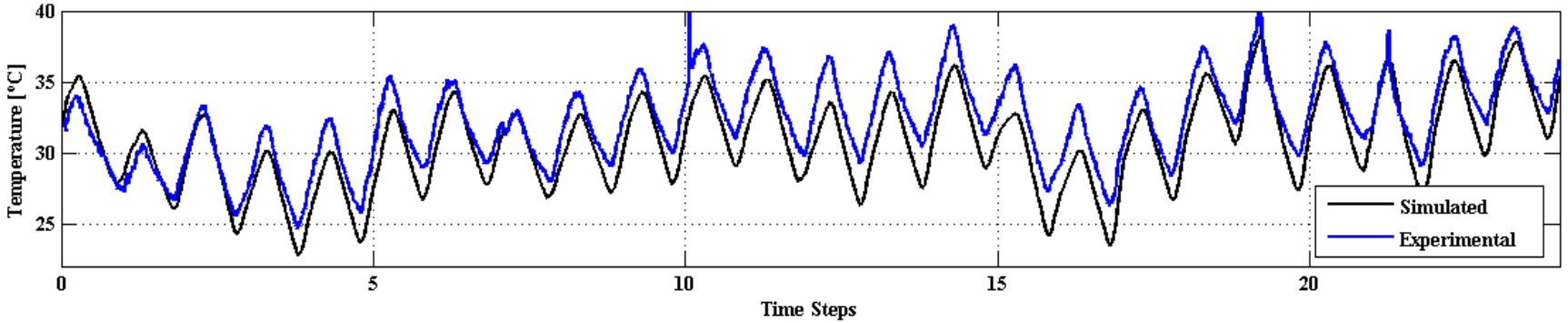

Temperature variation on the Top Wall of the container.



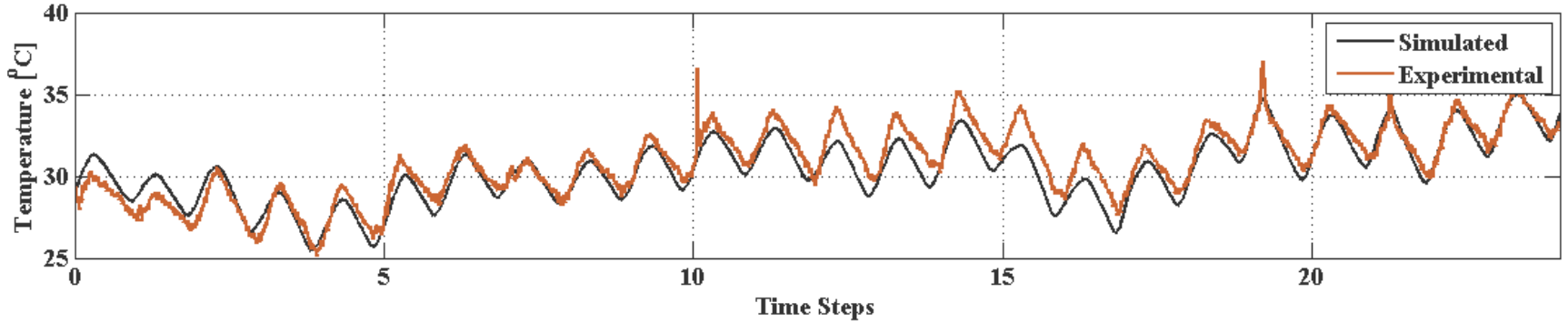

Temperature variation – Air Space High



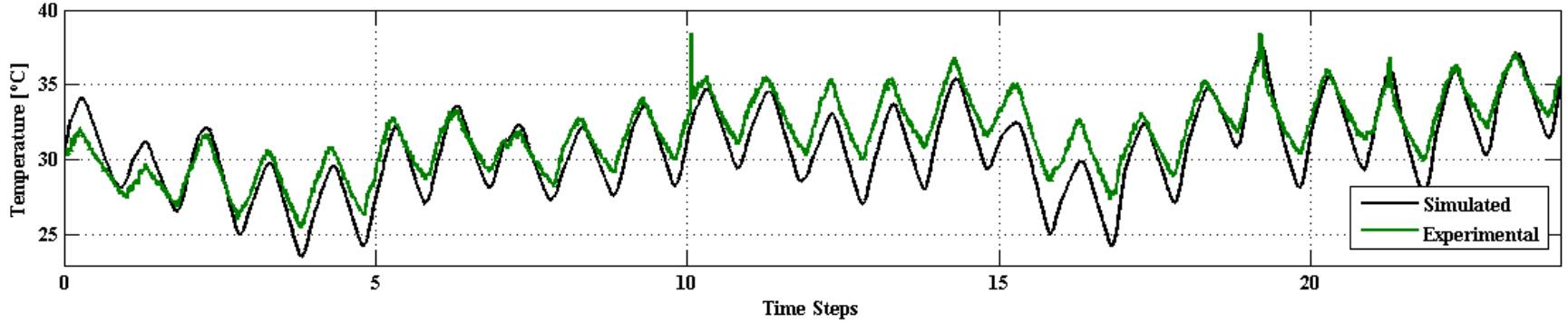

Temperature variation – Air Space Low




Pallet from the South-East corner of the container, bottle from the Top South-East corner of the pallet.

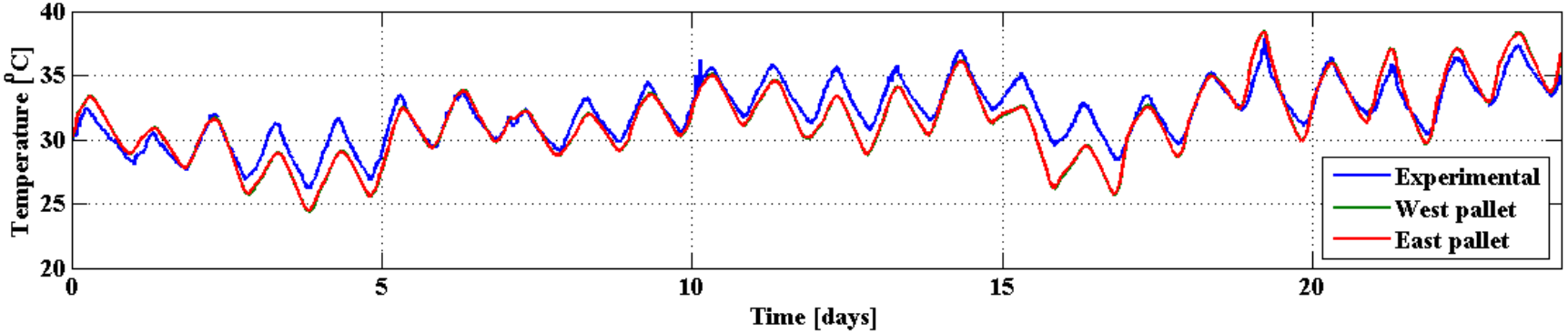



Pallet from the South-East corner of the container, bottle second from top South-East corner of the pallet.

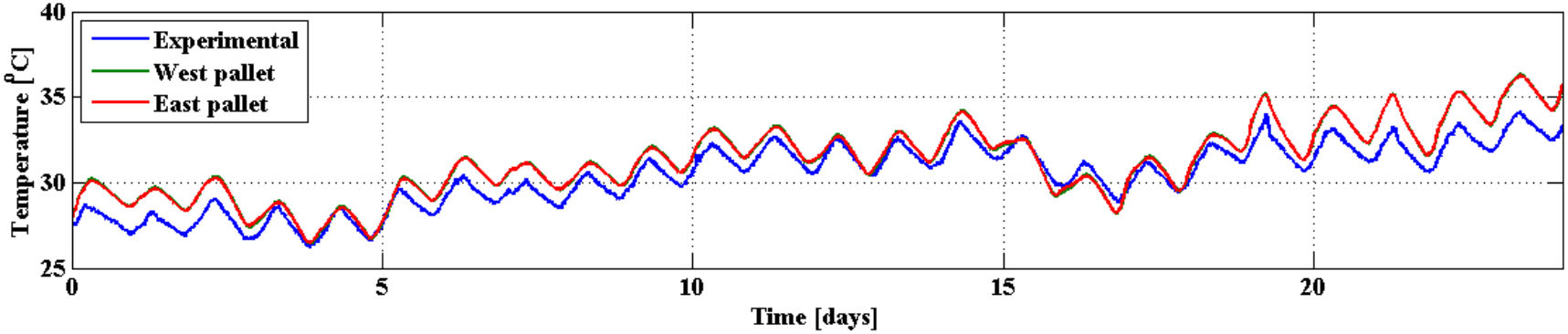



Pallet from the South-West corner of the container, bottle second from top South edge of the pallet.

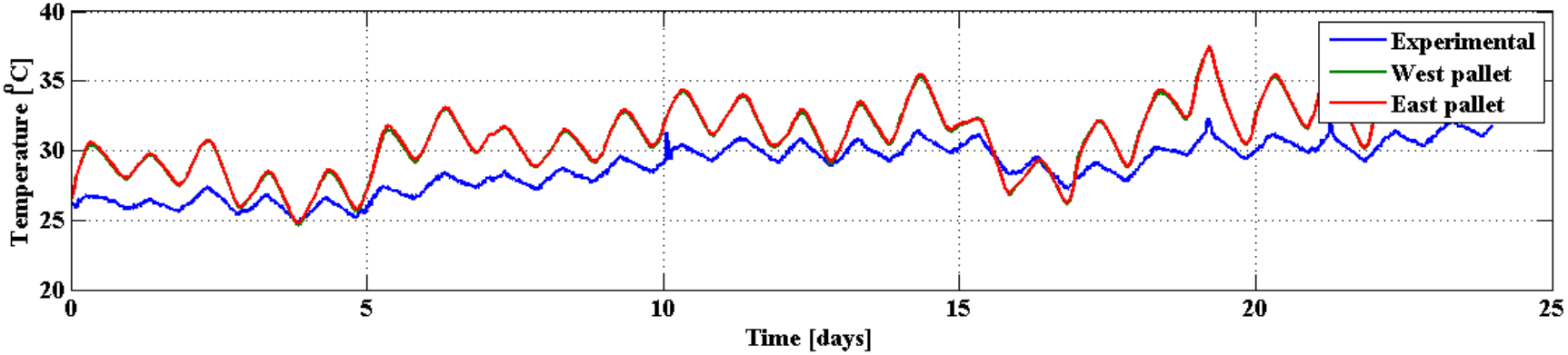
# Simulation results of the 2D CFD model




Temperature variation on the top layer of the pallet .

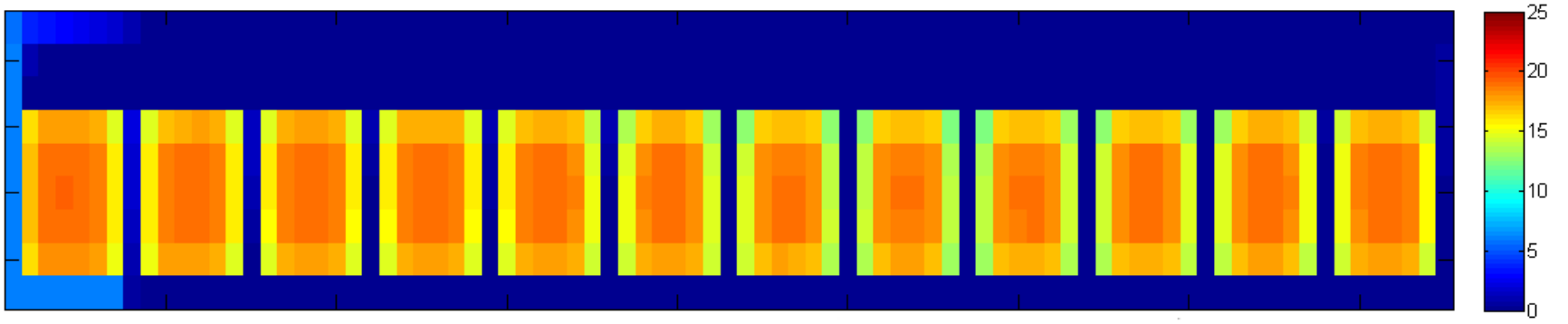



Temperature variation on the third layer from the top.

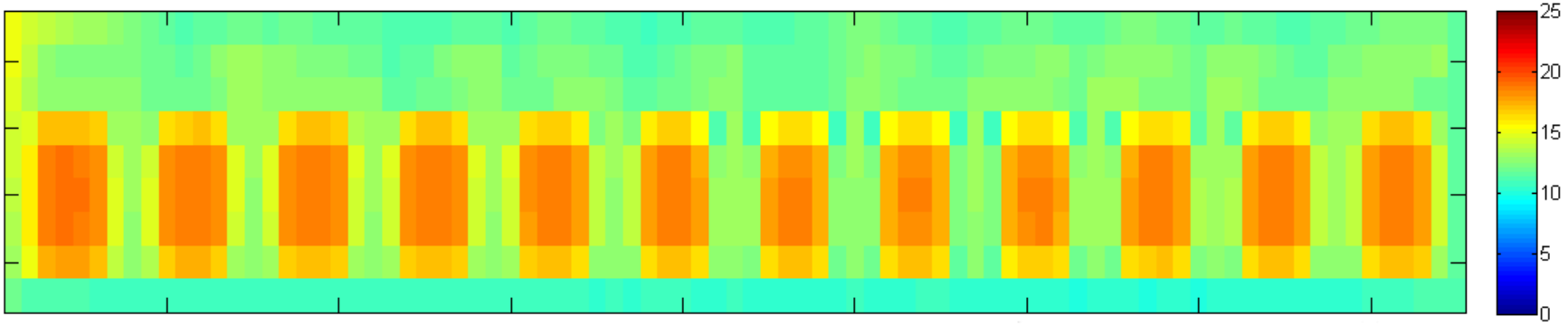



Temperature variation on the first layer from the bottom.

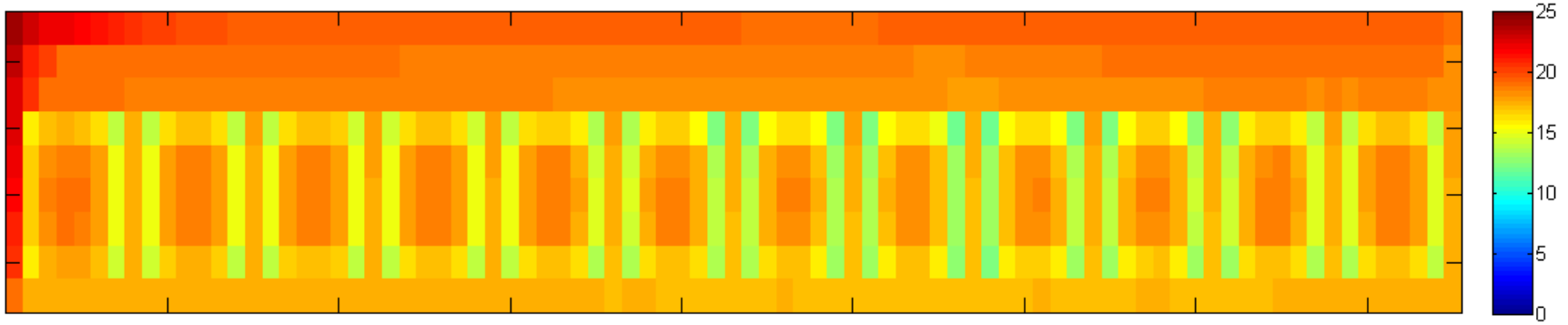
**Simulation results of the 2D 40ft container CFD model**




Cincinnati OH January 2nd 6 AM




Cincinnati OH January 2nd 9 AM




Cincinnati OH January 2nd 12 PM

## Future Work

- Improved Pallet Models

- Reduced Order Models of the container:
    * Proper Orthogonal Decomposition (POD)
    * Principal Component Analysis (PCA)
    * Kriging