# Coupling of a building and vegetation resolving urban microclimate model with a building energy simulation program

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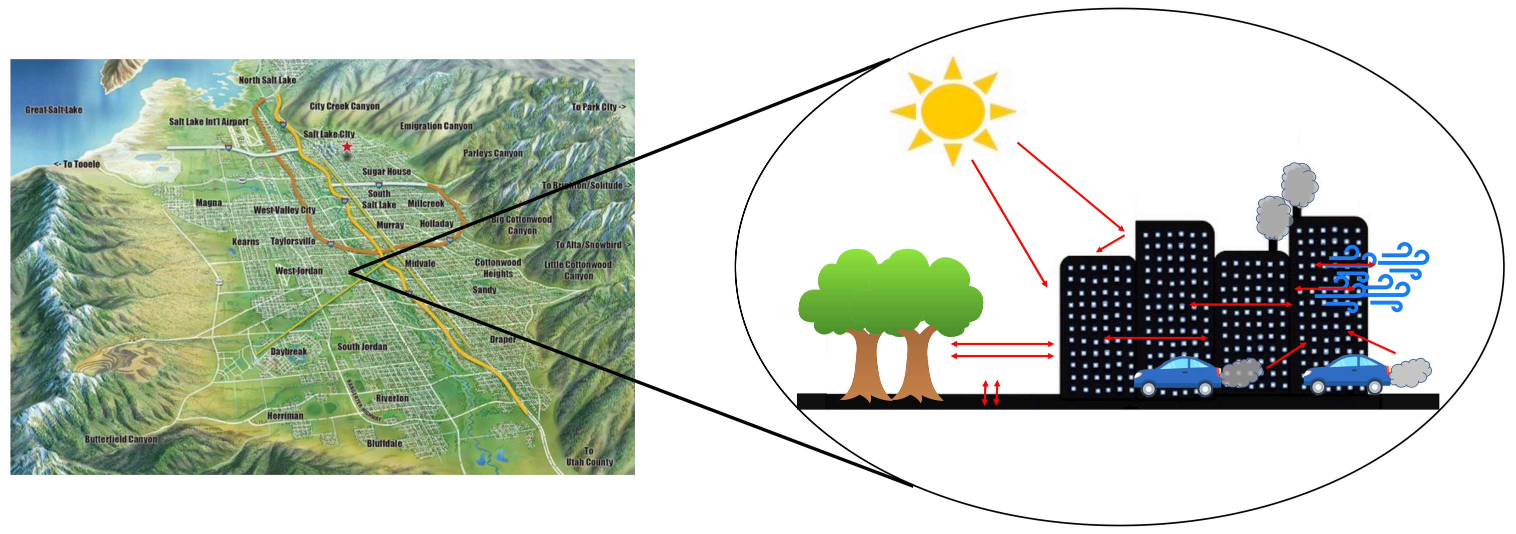
## Motivation

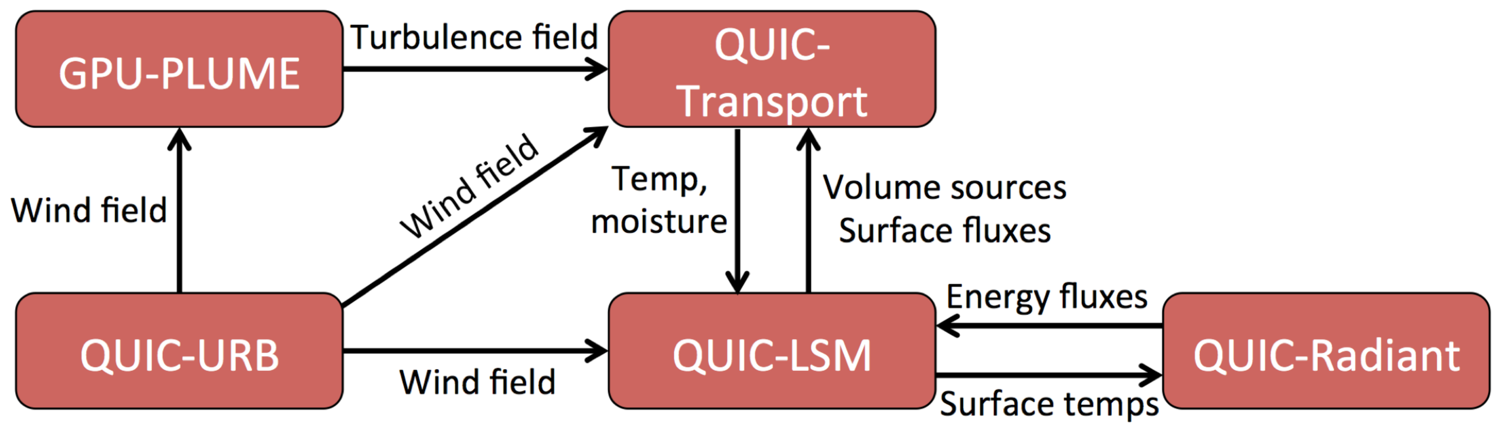
- **Buildings account for a substantial share of world energy consumption** and of the emissions in urban environments.
- **Building energy modeling is commonly used** by building energy system designers to predict and optimize building energy loads and operational schemes.
- **Building energy consumption** is generally affected by what is inside the building (such as occupants, appliances, HVAC systems, etc.) and by what is outside: the **weather conditions** the building is exposed to.
- Macro-climate conditions influence the regional weather,**micro-climate conditions influence the weather directly outside the building.**



The objective of this work is to **develop and validate a coupled fast-running Building Energy Modeling/Microclimate model** for use in developing site-specific design strategies which minimize energy and water use **All the micro-climate variables affecting the building energy consumption**, such as solar radiation, long wave radiation, air temperature, wind speed and direction, are taken into account. Differently from previous literature [1, 2, 3], we propose a **fully-dynamic coupling approach, fully surface-specific**, coupling EnergyPlus and QES.

## QES

**QUIC EnvSim:** Quick Urban Industrial Complex Environmental Simulation (QES) [4, 5, 6, 7, 8] - a robust, low-cost numerical simulation system that can represent a wide range of urban microclimate physical processes over a wide range of scales.



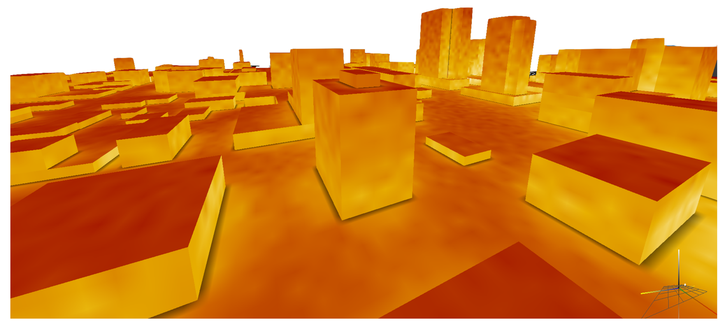

**QUIC Urb** is a mass consistent diagnostic wind model; it calculates the 3 dimensional mean wind characteristics around buildings. It employs empirical parametrizations to calculate the **initial wind fields** around complex urban geometries. Once the initial wind field has been solved, mass consistency is imposed.

**QUIC Plume** is a *random-walk* Lagrangian module, designed to run on GPUs. It calculates the **turbulence characteristics** required to simulate convective heat flux.

**QES Transport** calculates the distribution of temperature and moisture throughout a city. Heat and moisture exchanges between the atmosphere and urban canopies are calculated to compute a **local energy balance on each urban cell** in the domain.

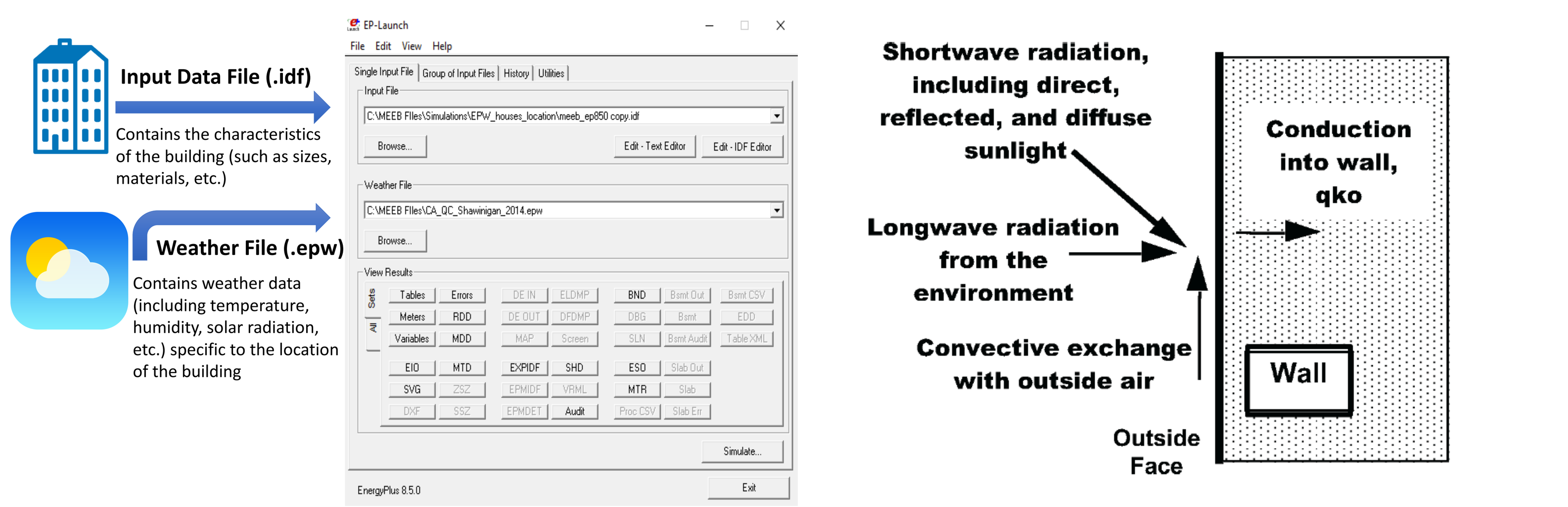
**QES Radiant** is a ray-tracing based radiative heat transfer model that calculates the **radiative heat flux** budget at surface in urban canopies including short-wave and long-wave heat fluxes on building surfaces.

**QES LSM** receives inputs from the other modules and **solves the surface heat balance**. Given the building internal surface temperature, LSM calculates the external surface temperature and the **conductive heat flux** that balances out the external convective heat flux, the long wave and the shortwave radiation heat fluxes.



For more details about QES, **refer to Talk 4D.8** of the current conference.

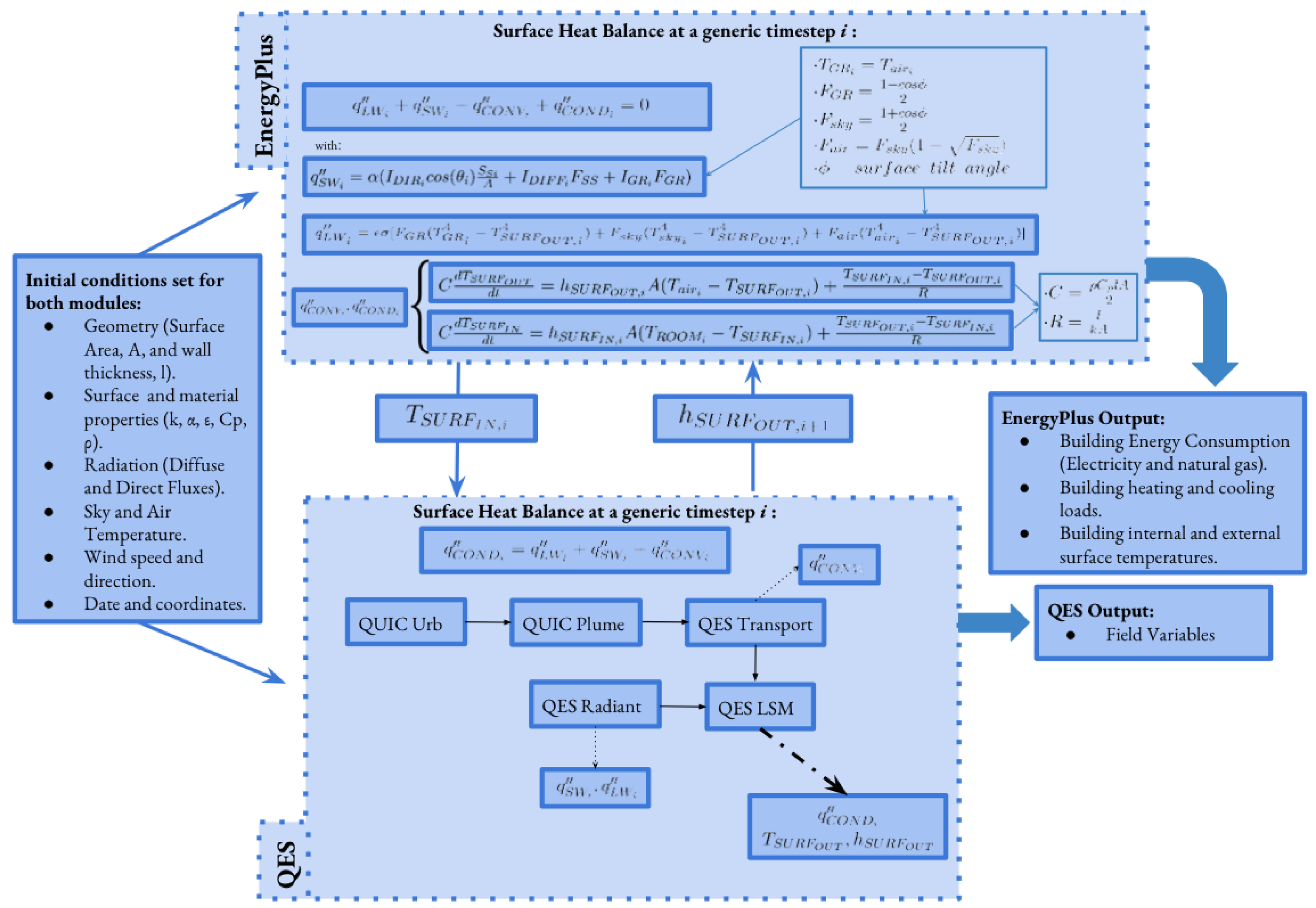
## EnergyPlus



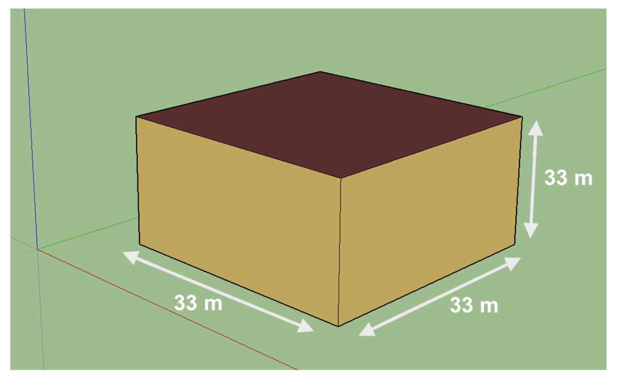

- Weather conditions are employed as boundary conditions for internal energy loads calculations.
- Well-known and supported DOE model with source code availability.
- Highly idealized boundary conditions.
- Complex flow around build not accounted for.
- Model assumes isolated buildings.

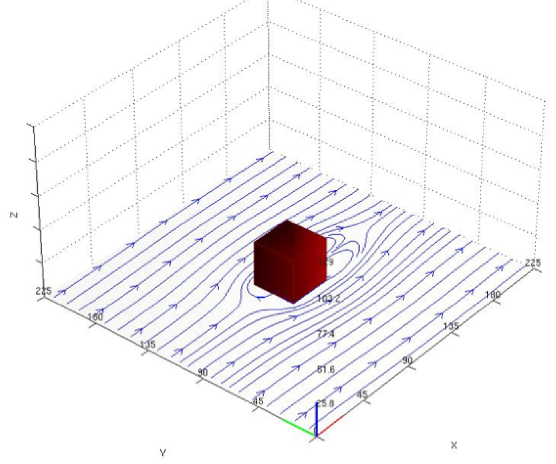
## Coupling Methodology

- The exchange of information between these 2 pieces of software was managed by a Python code.
- Full 24h simulations are performed in EnergyPlus for each timestep.



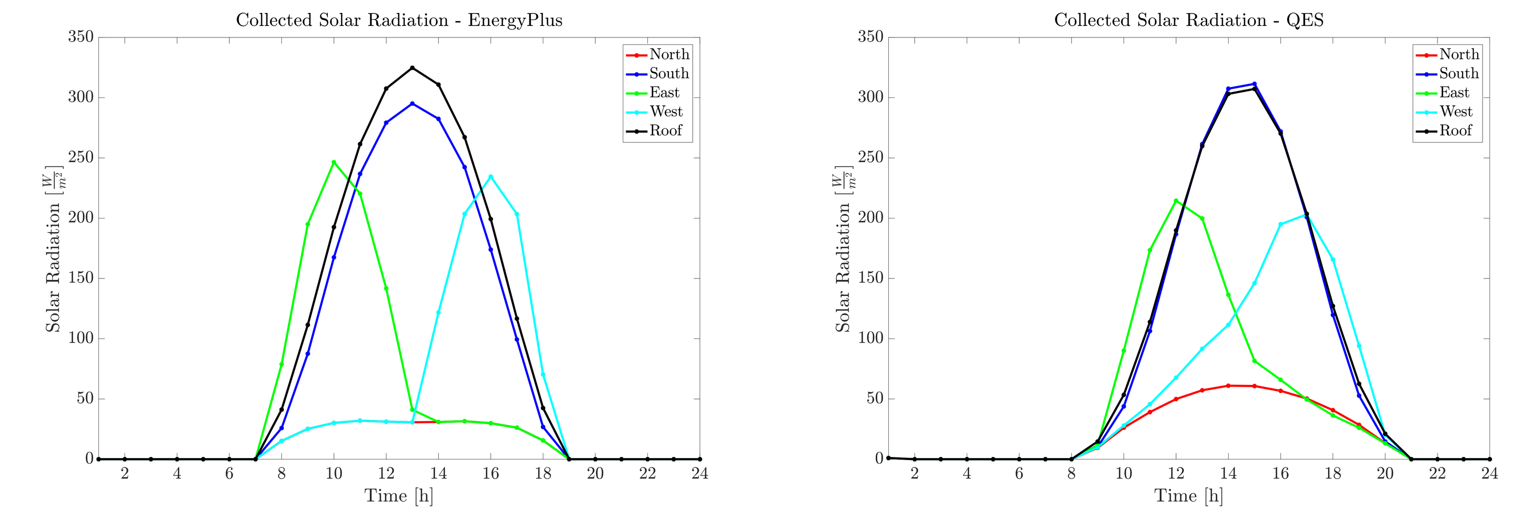

## Case Study



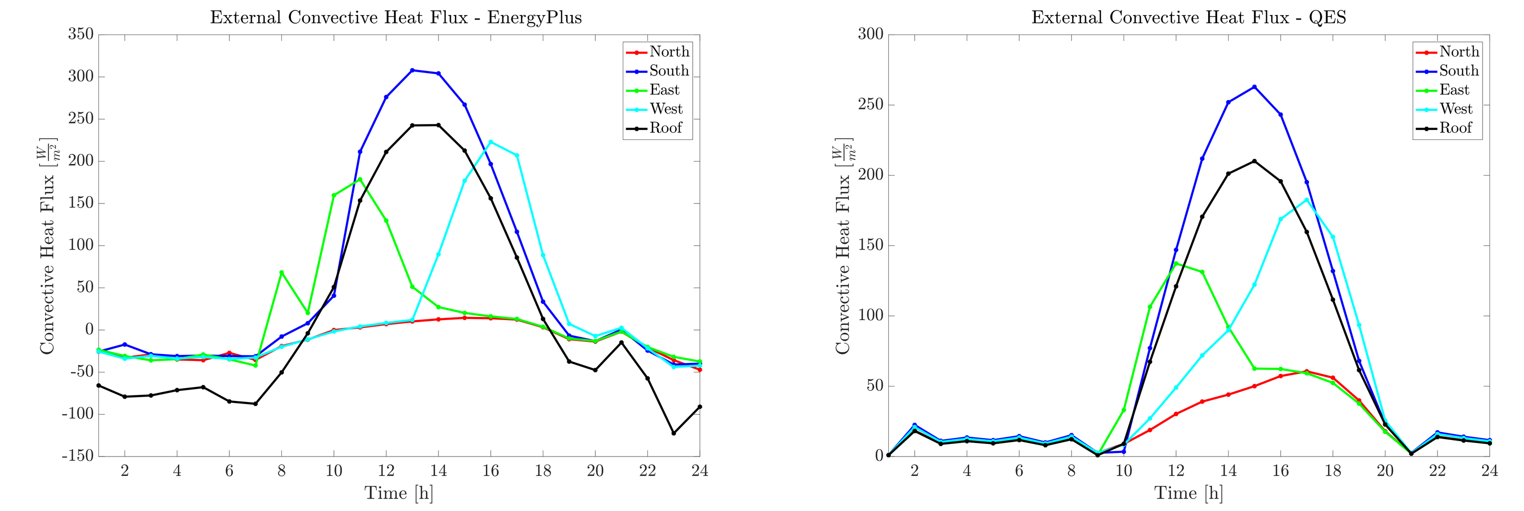



- No HVAC Systems (ideal loads).
- 1-h time-steps.
- Simulations for the 19th of March in Salt Lake City, UT (40.7608 N, 111.8910 W).
- Material properties for red-brick.
- 33m x 33m x 33m; 0.9 m thick.
- Wind direction = 262°
- Inlet wind speed = 3.8 m/s
- Ambient air temperature = 23.6°C
- Logarithmic inflow conditions

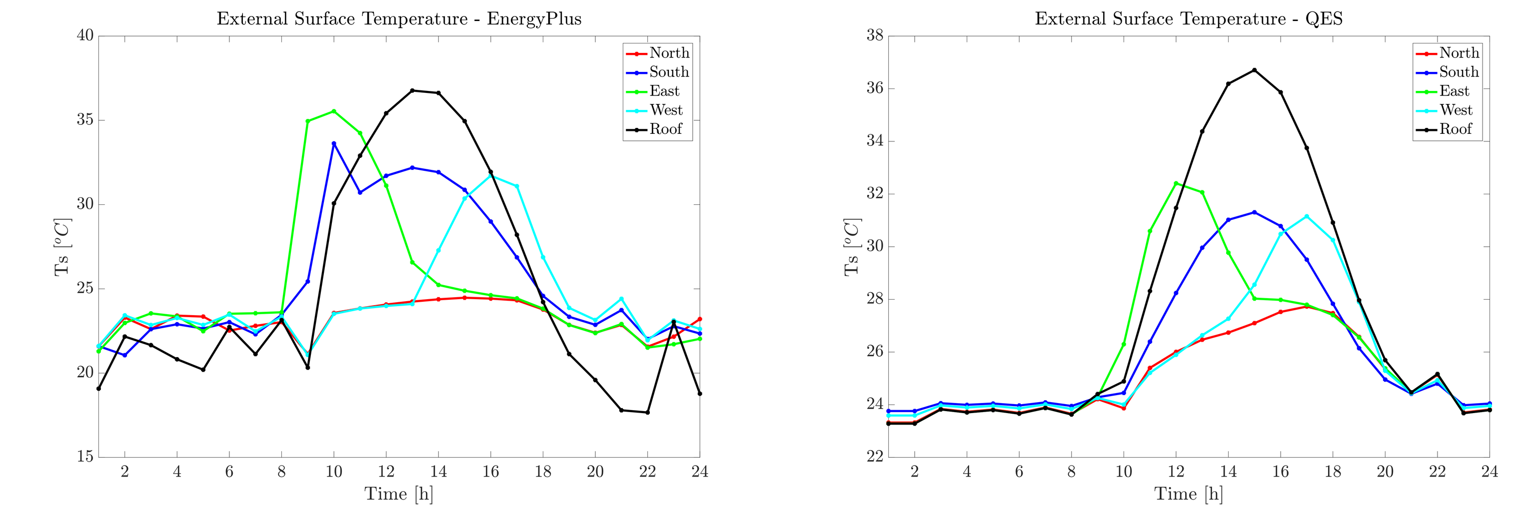
## Results and Discussion



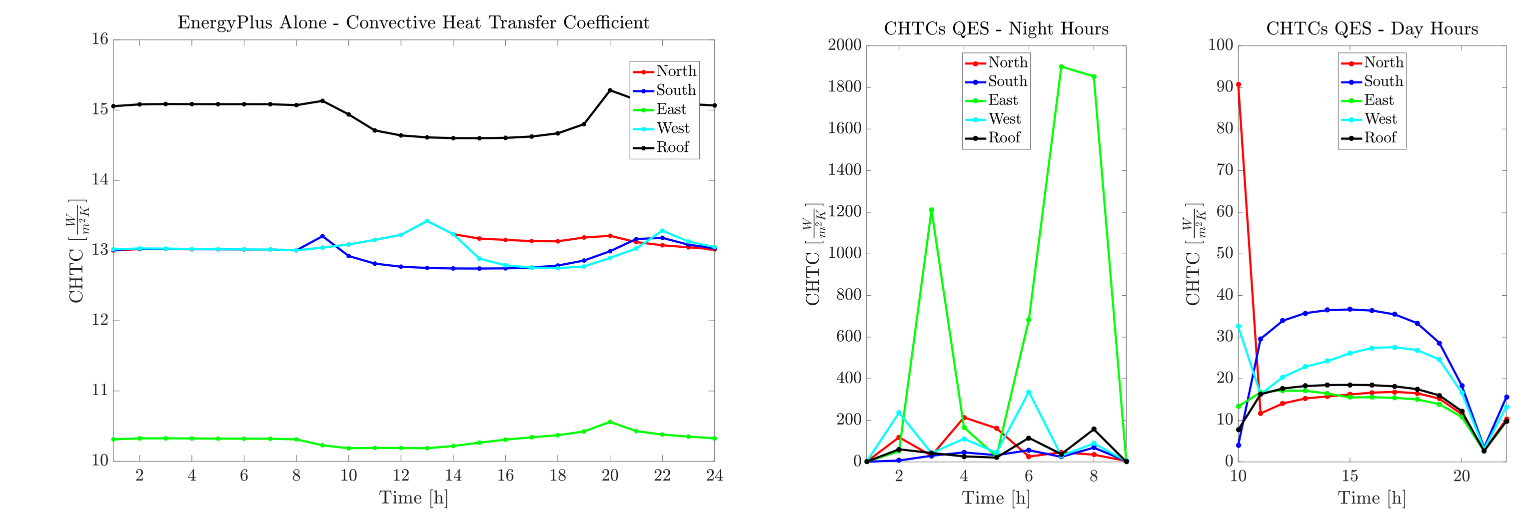

*Comparison of incoming solar radiation between EnergyPlus and QES*




*Comparison of external convective heat fluxes between EnergyPlus and QES*




*Comparison of external surface temperatures between EnergyPlus and QES*




*Comparison of external CHTCs between EnergyPlus and QES*

**Proof of concept of coupling QES and EnergyPlus has been demonstrated**
**Results are sensitive to QES's surface sensible heat flux model at night, when temperature gradients are very weak, which must be improved.**
**Future work should include passing radiation and vegetation.**

## References

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