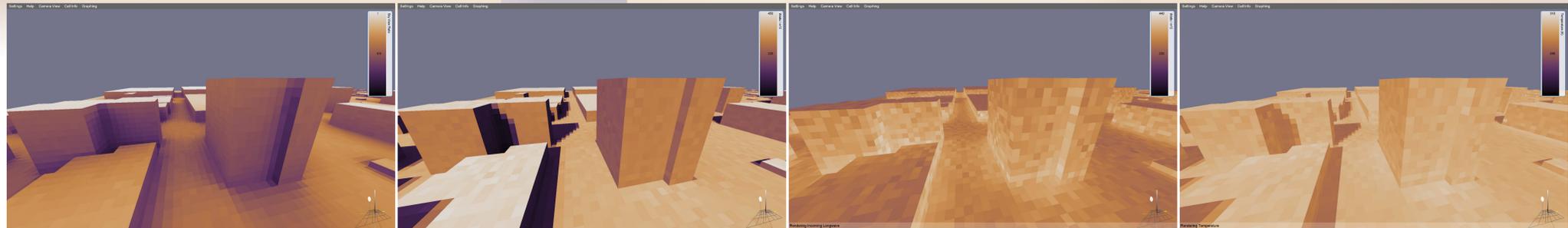


# Visualization and Exploration of Urban Microclimate Simulations using the QUIC EnvSim GPU Framework

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QUIC EnvSim is capable of rapidly computing several scalar fields over the surface of a domain by taking advantage of the processing power of Graphical Processing Units (GPUs). In under a minute, we are able to compute the above scalar

fields on a domain representing downtown Salt Lake City at a resolution of 4m. These scalar fields are, from left to right, the skyview factor, the net shortwave radiation, the longwave radiation, and the resulting patch temperature.

## Abstract

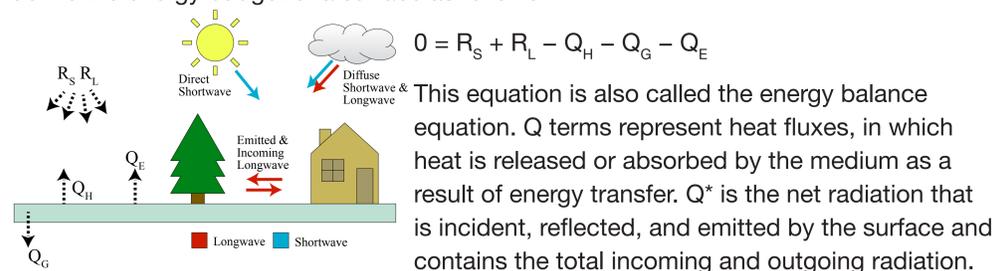
QUIC EnvSim (QES) is a modular framework for efficiently simulating and visualizing building scale environmental interactions in urban domains. QES leverages the computational resources available on both modern graphics hardware cores (GPUs) and CPUs to efficiently simulate complex interactions between the built environment and environment scalars such as heat and moisture. Visualizing simulation results enables users to analyze the data, to understand the interactions with the environment, and to communicate processes to urban planners, stakeholders, and decision makers.

The speed and efficiency of QES comes from its utilization of GPUs to perform simulation computations in parallel. A synergistic side effect of performing computation on the GPU is that much of the data resides directly in GPU memory and can therefore be visualized immediately upon completion of a simulation timestep. QES' visualization interface provides control over the simulation and allows for direct presentation of environmental scalars, including sky view factor, solar and longwave radiation, and temperature across the simulation domain.

Alternative visualization components of QES render the data external to the simulation but afford more advanced rendering of the domain data. In one such system, a headmounted display gives users a firstperson perspective on the simulation, allowing users to see scalar fields change around them over the course of a diurnal cycle. A virtual reality tracking system is also used to track user movements, gestures, and actions providing users with natural mechanisms to navigate through and interact with the data. Such vantage points and interactivity may be beneficial for communicating how differences in urban structure impact local changes within an urban domain. The viability of these interfaces over standard presentations is an open question that we are currently exploring. Our working hypothesis is that through compelling visuals and effective interaction techniques, urban environmental processes can be more directly communicated to users.

## What Is QES?

All objects have an energy budget that defines the relation of incoming, outgoing, and stored energy. This energy budget is used to calculate surface temperatures in QES. We define the energy budget of a surface as follows:



$Q_H$  is the sensible heat flux, a direct result of the exchange of heat through conduction and convection. For example, when a cool surface is heated by a warmer air temperature, its sensible heat flux will increase.  $Q_E$  is latent heat flux and is produced during a phase change with a constant temperature, such as the evaporation of water. The energy required to make this phase change comes from the water.  $Q_G$  is ground heat flux, also known as conductive heat flux, in which energy is transferred to connected or subsurface layers. Each of these terms represent a component that QES models and simulates.

Solving this equation at every surface in the domain enables us to explore the effects of urban form on the environment. QES contains integrated models that simulate the transport of heat and moisture in urban domains. QES' Turbulent Transport Model (TTM), Land Surface Model (LSM), and Radiative Energy components are tightly coupled to simulate the interaction of scalars across a variety of surface, vegetative, and air boundaries.

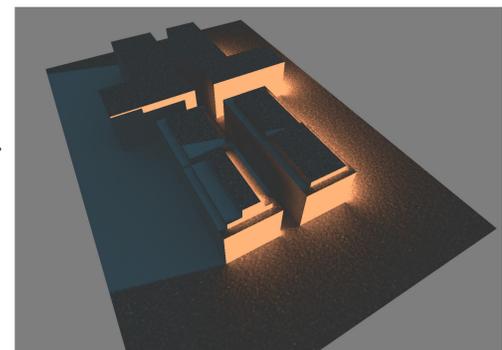
Using QES, we can investigate the climatic consequences of urban layouts, materials, vegetative infrastructure, and more by evaluating and modeling this equation. The focus of current research and future works will be the development of an energy balance equation for vegetation in urban domains.

## Importance of Visualization



We are able to simulate and visualize volumetric scalar fields in addition to surface scalar fields. On the left, we are visualizing a simulation of energy transport in downtown Salt Lake City. The air temperature is shown as a traditional volume visualization, and clipping planes at back show the values on those planes and additional isocontours to make the data structure more easily visible.

We have made an effort to allow the visualization of results at many stages of our research, and this has allowed us to iterate more rapidly and catch errors more quickly. Simple errors, such as an improper conversion from solar azimuth and elevation, can be easily caught by seeing the visual results. In other situations, early visual analysis can suggest potential weaknesses of datasets being used. The image to the side shows the change in incoming solar flux for a validation dataset where we were examining an urban canyon. This drastic visual change corresponds to an insolation of over 1,000 W/m<sup>2</sup>. Although this extreme value was not present in our measurements from inside the canyon, it reinforced the increased noise level that results from computing total solar flux from a single upwards-facing sensor.



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