Prototype Heat Island Application

PHOENICS-2011
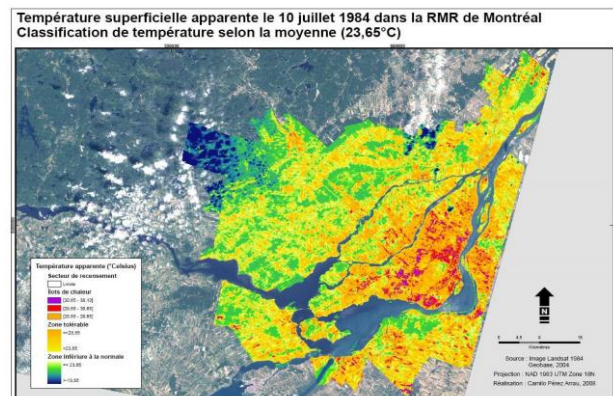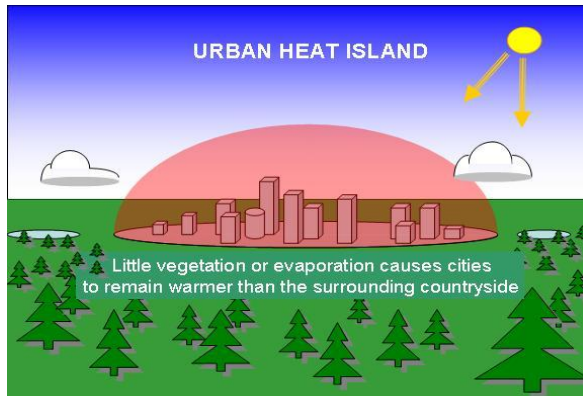
Introduction

Heat islands are large-scale phenomena in which the general urban temperature level rises above that of the rural surroundings. The main cause of the heat-island effect is the absorption by and emission of radiation by hard-surfaced man-made objects (buildings and roads). The sun falls on vegetation and on cities at the same rate; but the vegetation absorbs the incoming radiation in depth, is better cooled by the air in which it is immersed and can lose heat by evaporation. Hard surfaces by contrast quickly attain the temperatures which enable them to emit nearly as much radiant heat as they gain (the difference being lost by convection).

Unlike the large-scale Air Ventilation Assessment (AVA), heat island simulation does not require that the detailed geometry of buildings be captured; rather it is the amount of solid surface per unit volume, and its emissivity, which is decisive. The 'sunlight' object in PHOENICS can compute the intensity and direction of incoming radiation and its distribution upon surfaces, and the Immersol feature is ideally suited to handling the redistribution of radiation between buildings by reflection and re-radiation.

To date, little simulation of heat island phenomena has taken place. However, investigation into heat islands, their causes and effects, is becoming an increasingly important across the globe, especially, as one might expect, in highly urbanised environments.

A new PHOENICS-based prototype heat island model has been developed in response to that demand and forms a flexible template for the investigative engineer to use.
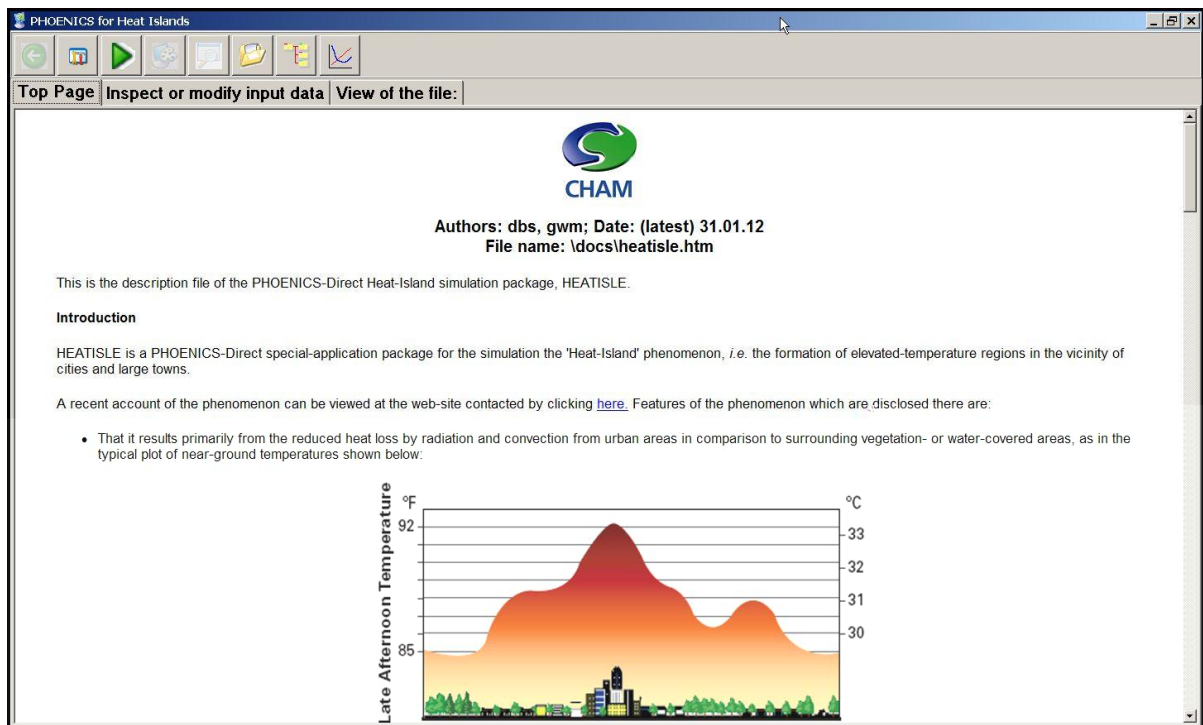

The new menu-driven interface is designed for those many potential users who do not have time to learn to use the standard VR-Editor or VR-Viewer but who still want to enjoy the benefits of CFD through utilisation of pre-prepared case files.   The creator of the Q1 and the associated soc.xml decides which parameters will be made easy for these users to set and which default views it will be made easy for them to select and display.
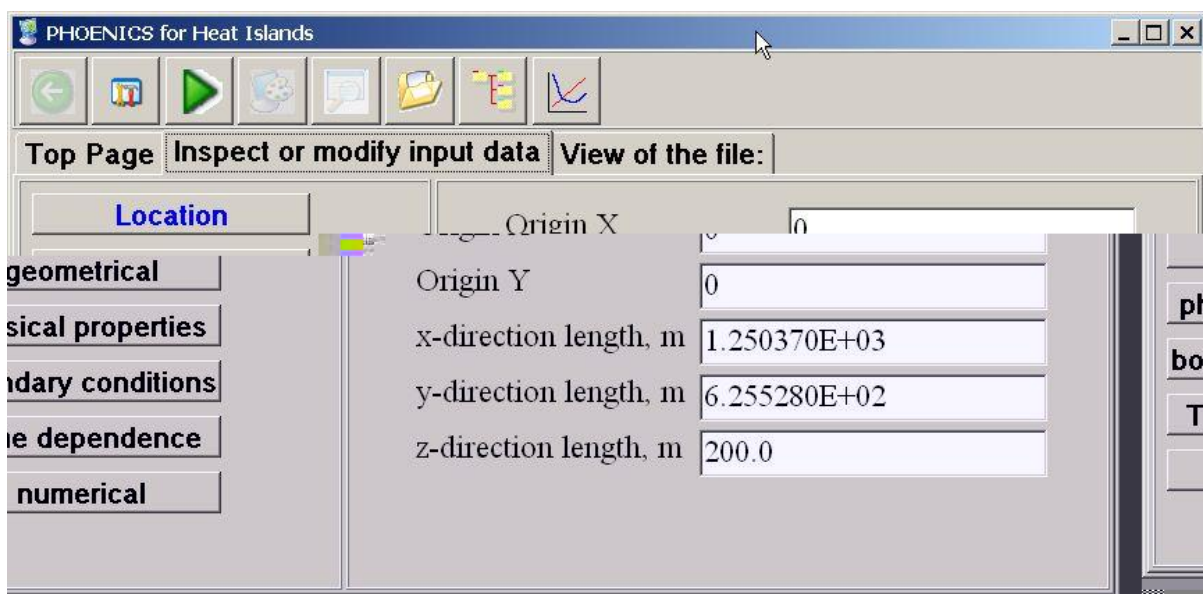
This optional menu transmits the Q1 and frommenu.htm to the working directory, runs the case there and leaves its files there. At that point, users have the option to start to run PHOENICS via PHOENICS-VR in the usual way, *i.e.* without further use of the menu, or to remain within the pre-selected menu structure.
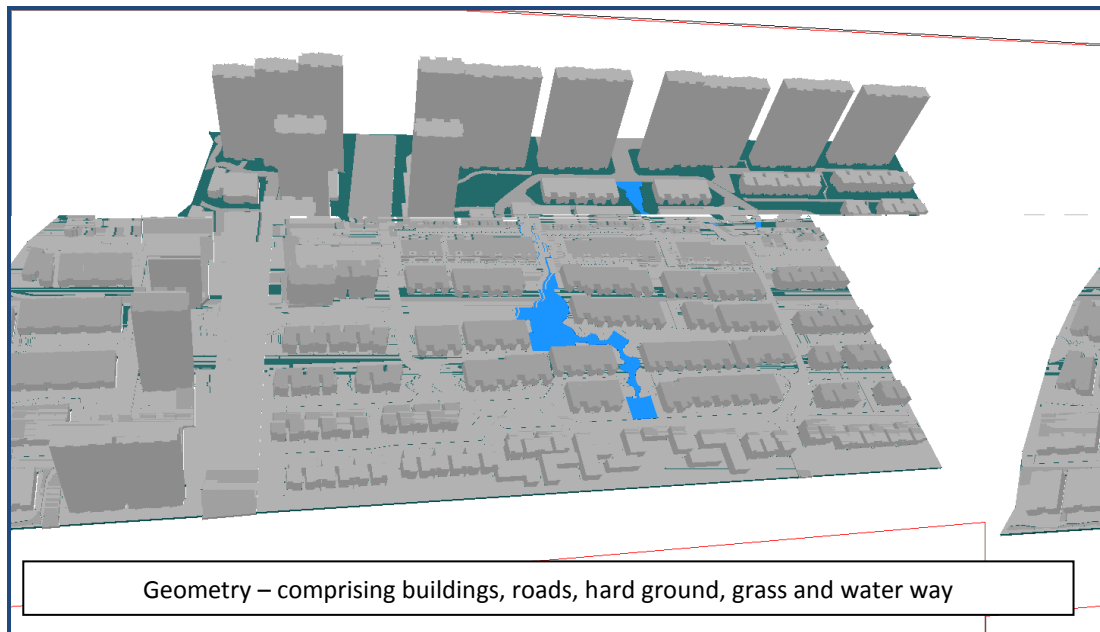
Geometry – comprising buildings, roads, hard ground, grass and water way

The idealised geometry shown above contains many of the components of interest to the "Heatisle" engineer; viz, concrete and glass high rise buildings, tarmac roadways, hard terrain and vegetation, and a water course.   Each component responds differently to solar radiation.

Sun position

Noon

North

Wind direction

Mesh
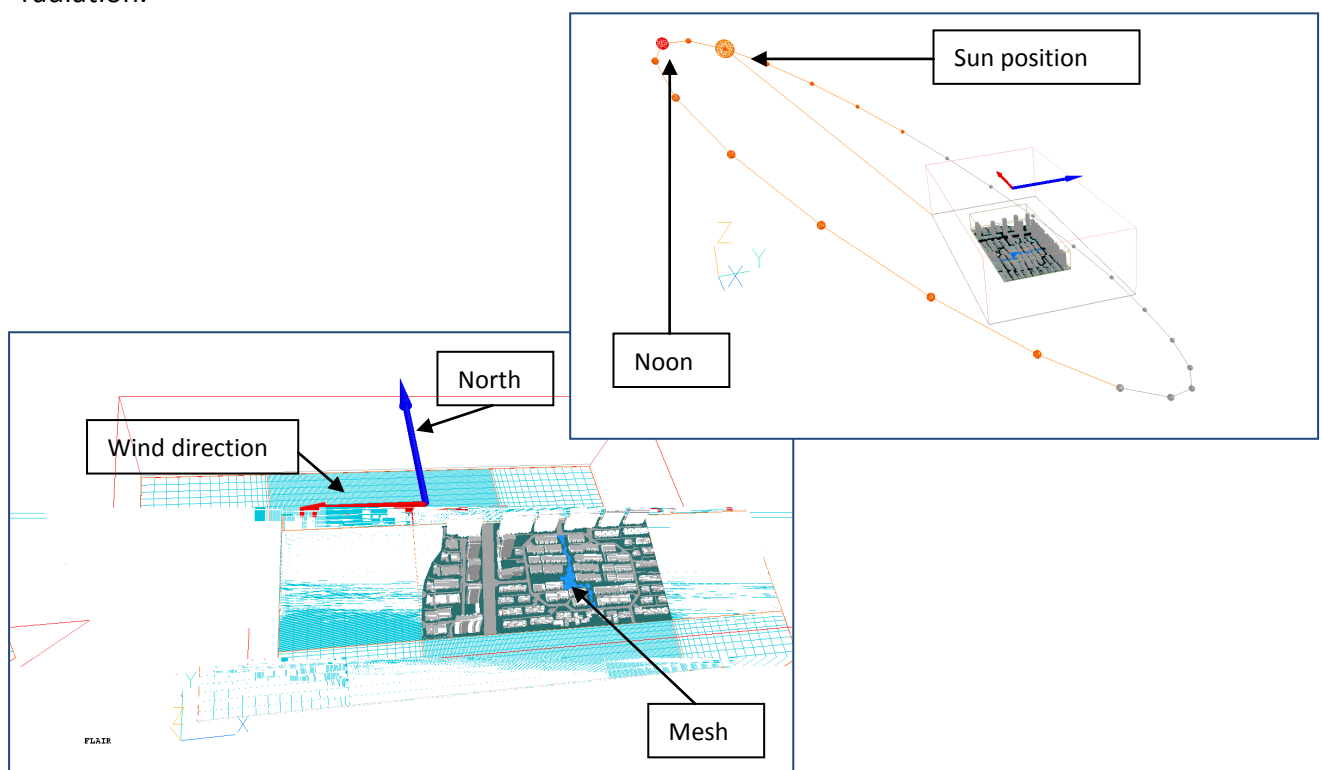
In our hypothetical 'test' case, the wind and sun conditions are representative of the UK (at Gatwick) in April.

- Wind direction - East
- Wind speed - 2.5 m/s at 10m
- Logarithmic wind profile
- Roughness height - 0.1m
- Ambient temperature - 12˚C
- Ground temperature - 9˚C
- Sun latitude 51deg
- Direct radiation 400 W/m2
- Diffuse radiation 100 W/m2
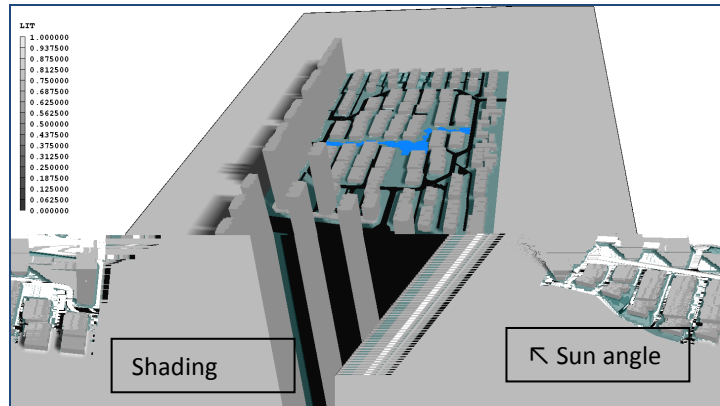
In this example, the ground surrounding the buildings, road, grass and river all have a Z depth of 2m. The ground temperature of 9˚C is applied at the lower face of the ground. This represents the constant earth temperature underground.

The radiative heat transfer is handled by IMMERSOL. The surface emissivities are set as follows:

Ground - 0.9
Grass - 1.0
Road - 0.5
River - 1.0
Building - 1.0

The radiative heat loss to the sky is represented by a radiative heat loss to an external temperature of -2˚C with an emissivity of 1.0.

It should be noted that in order to radiate 500w/m^2 to an external temperature of -2˚C, the required temperature is 72˚C. After around 1200 sweeps the average temperature over the entire ground plane just below the surface is 67˚C. The temperature of the road which has a lower emissivity is higher, again in line with expectation. However, given that the surface temperatures are not actually that high in reality, there must be some other mechanism for heat loss.

Although in this case the model is set with user-defined inputs, both the sun and wind parameters can be imported from an EPW weather file (eg the public domain Energy Plus database.)

Current Limitations (as of February 2012)

1. The absorptivity of all surfaces is assumed to be 1.0. It is intended to allow for separate absorptivity and emissivity for each object. There remains a question as to what to do with the heat which is not absorbed.

2. The radiation model does not work well with PARSOL. If only a few cells are cut this does not represent a problem. However, if the majority of the fluid-solid surface is composed of cut cells the model will give incorrect solutions.

3. In a transient case, the time variation of wind speed and direction (and temperature) can be taken from a weather file. If a weather file is not being used, separate WIND objects with consecutive time limits will be needed for each wind direction.
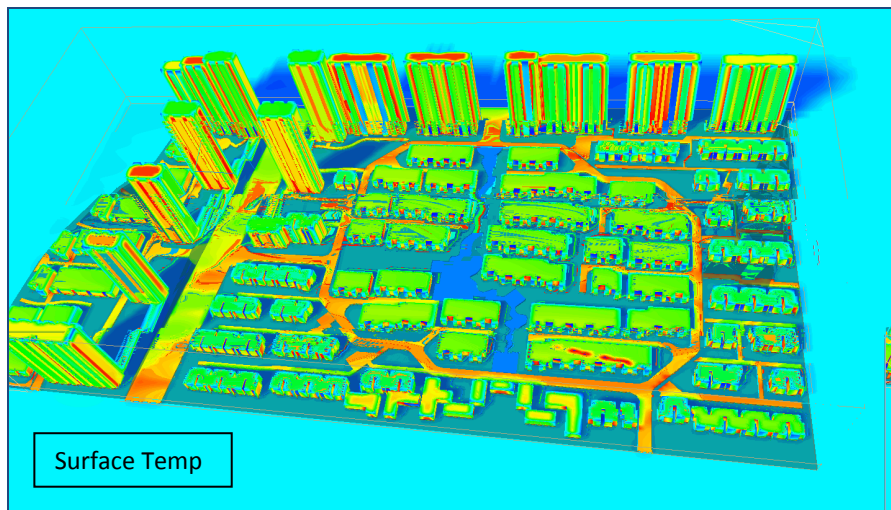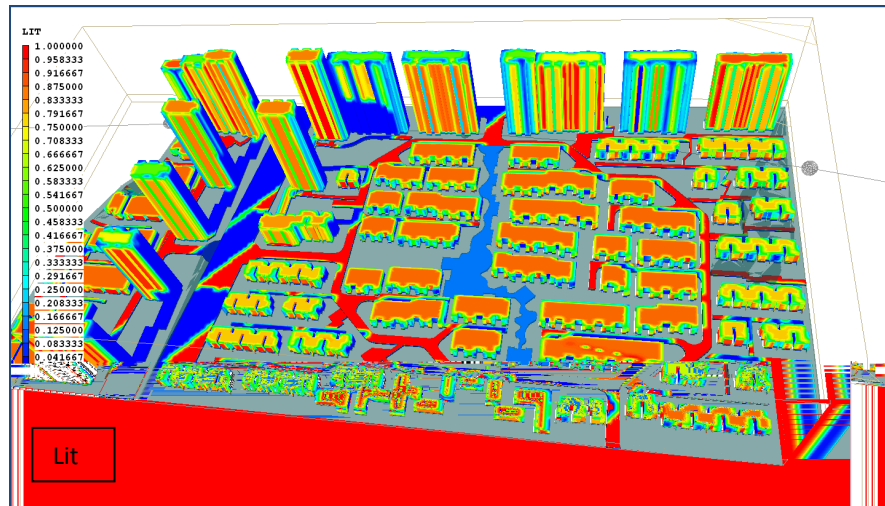
Conclusion

The prototype heat island module demonstrates adequately the ability of PHOENICS to simulate processes of this type. Whilst there is already connectivity with weather mapping data bases, the module still remains as a working template, relying upon the user to specify appropriate materials, and their emissivity and absorptivity values.

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