

UNR's Universal Thermal Model for RA Thermal Rating Verification

Presented by

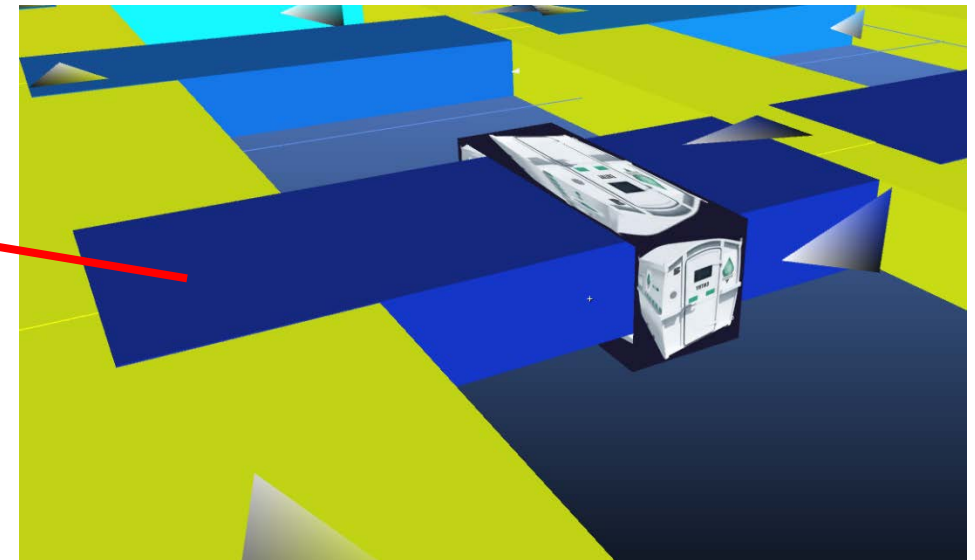
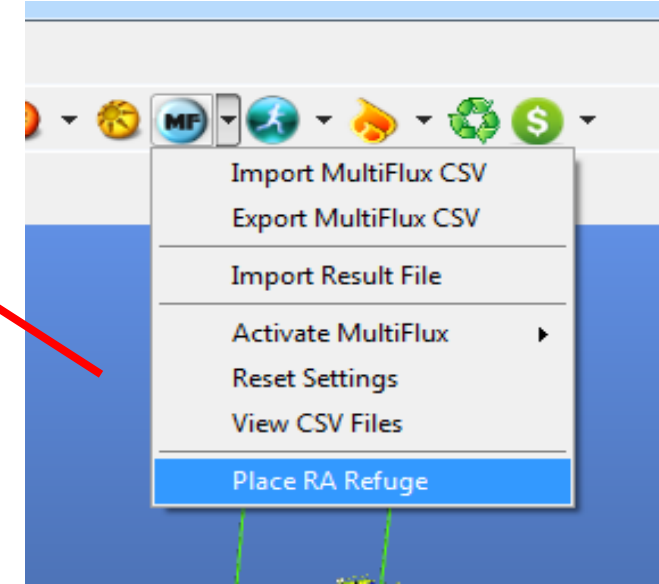
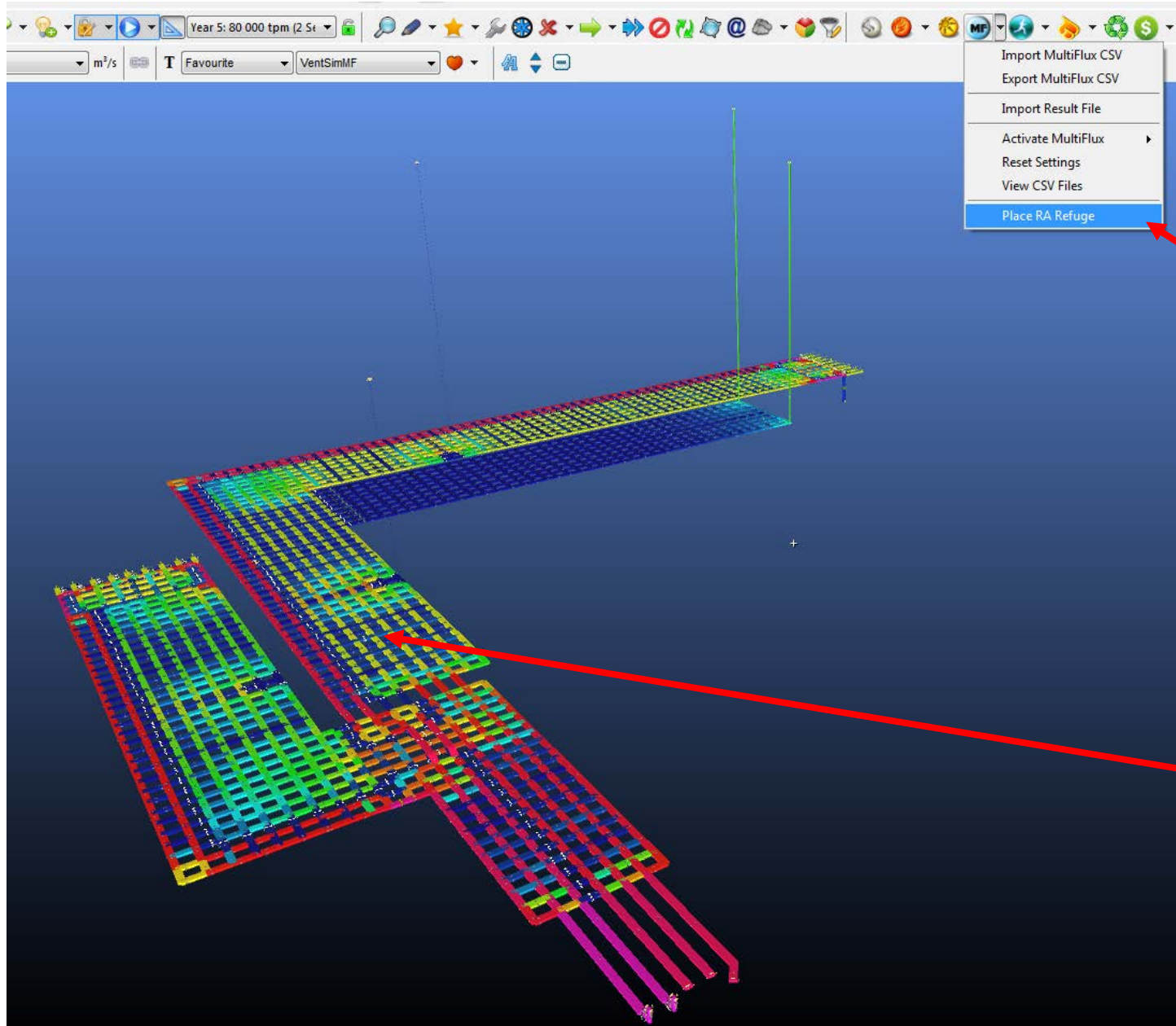
Dave Yantek, NIOSH Pittsburgh Center

Contributed by

Davood Bahrami and George Danko, UNR (MULTIFLUX thermal model)

Craig Stewart and Craig Christensen, Chasm (Ventsim graphical User Interface)

Insertion of the location of the RA in the mine in Ventsim's GUI

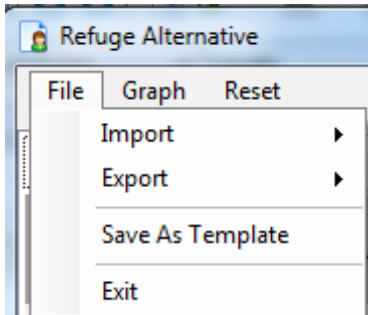


Simple mine layout: manual insertion of an RA



Data input tab for the RA in the GUI

File menu options



The main screenshot shows the 'Refuge Alternative' application window. The title bar reads 'Refuge Alternative'. The menu bar contains 'File', 'Graph', and 'Reset'. A 'Select Template' dropdown menu is on the right. Below the menu bar is a tabbed interface with the following tabs: 'Room' (selected), 'HSE Data General', 'HSE Data Individual', 'Scrubber', 'Inside Conditions', 'Outside Conditions', 'RA Insulation', and 'Miscellaneous'. The main content area is titled 'Refuge Alternative User Input Template' and contains several sections of input fields:

- Capacity**
 - Number of rows of occupants along length: 5.00
 - Number of occupants in each row: 2.00
- Main Shelter Room Dimensions**
 - Length: 6.000 m
 - Width: 2.90 m
 - Height: 1.06 m
- Utility Room Data**
 - Length: 0.99 m
 - Width: 1.97 m
 - Height: 1.06 m
 - Thickness: 0.01 m
 - Thermal Conductivity: 50 W/m-k
 - Heat transfer Coefficient Multiplier: 1
- Connection between Utility Room and Main Shelter Room**
 - Open connecting cross section surface area (%) (Percent of width x height of the RA): 100 %

On the right side of the input fields, there is a 3D rendering of a white, box-like shelter with a green door and a green logo. The door has the word 'ENTRY' written on it.

At the bottom of the window, there are several buttons: 'RUN' (with a green play icon), 'Open Location' (with a folder icon), 'Save Location' (with a floppy disk icon), 'OK' (with a green checkmark icon), and 'Cancel' (with a red X icon).

Data input tab for the RA in the GUI

The screenshot shows a software window titled "Refuge Alternative" with a menu bar (File, Graph, Reset) and a "Select Template" dropdown. The "Room" tab is active, showing a sub-tab "HSE Data General". The main area is titled "Refuge Alternative User Input Template" and contains a section for "General Human/Scrubber/Equipment Data".

Parameter	Value	Unit
Contact Surface with floor	0.2	m
Height in % of the RA height	71.9	%
Mass	10.0	kg
Specific Heat	4200.0	J/kg-K
Outer Surface Area	1.8	m ²
Metabolic heat dissipation per person	120.0	W
Moisture generation per person	1.0	L/day
Thermal conductivity	50	W/m-K
Human initial temperature	36	oC
Heat transfer coefficient multiplier	1	W/m ² -K

At the bottom of the window, there are buttons for "RUN", "Open Location", "Save Location", "OK", and "Cancel".

Data input tab for the RA in the GUI

Refuge Alternative

File Graph Reset Select Template

Room HSE Data General **HSE Data Individual** Scrubber Inside Conditions Outside Conditions RA Insulation Miscellaneous

Refuge Alternative User Input Template Auto Position

Individual Human/Scrubber/Equipment Data

	Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
▶	1	0.3	0.51	1	1
	2	0.3	2.39	1	1
	3	1.51	0.51	1	1
	4	1.51	2.39	1	1
	5	2.71	0.51	1	1
	6	2.71	2.39	1	1
	7	3.91	0.51	1	1
	8	3.91	2.39	1	1
	9	5.12	0.51	1	1
	10	5.12	2.39	1	1

Y---->

1 2

3 4

5 6

7 8

9 10

RUN Open Location Save Location OK Cancel

Data input tab for the RA in the GUI

Refuge Alternative

File Graph Reset Select Template

Room HSE Data General HSE Data Individual Scrubber Inside Conditions Outside Conditions RA Insulation Miscellaneous

Refuge Alternative User Input Template Auto Position

Individual Human/Scrubber/Equipment Data

	Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
▶	1	0.3	0.51	1	1
	2	0.3	2.39	1	1
	3	1.51	0.51	1	1
	4	1.51	2.39	1	1
	5	2.71	0.51	1	1
	6	2.71	2.39	1	1
	7	3.91	0.51	1	1
	8	3.91	2.39	1	1
	9	5.12	0.51	1	1
	10	5.12	2.39	1	1

Y---->

1 2

3 4

5 6

7 8

9 10

RUN Open Location Save Location OK Cancel

Auto Position:
Default uniform arrangement of occupants

Data input tab for the RA in the GUI

Modified arrangement of occupants by manually moving the occupants or entering new data

The screenshot shows the 'Refuge Alternative' software interface. The 'HSE Data Individual' tab is active, displaying a table of occupant data and a 2D layout of a room with 10 numbered green circles representing occupants.

Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
1	0.81	0.48	1	1
2	0.3	2.39	1	1
3	1.51	0.47	1	1
4	1.06	2.42	1	1
5	2.21	0.47	1	1
6	3.19	2.43	1	1
7	4.33	0.48	1	1
8	3.91	2.39	1	1
9	5.12	0.51	1	1
10	4.69	2.40	1	1

The 2D layout shows a light blue rectangular area representing the room. Ten green circles, numbered 1 through 10, are arranged in two vertical columns. The left column contains circles 1, 3, 5, 7, and 9. The right column contains circles 2, 4, 6, 8, and 10. The circles are positioned to match the X and Y coordinates from the table above.

At the bottom of the window, there are buttons for 'RUN', 'Open Location', 'Save Location', 'OK', and 'Cancel'.

Data input tab for the RA in the GUI

Refuge Alternative

File Graph Reset Select Template

Room HSE Data General HSE Data Individual **Scrubber** Inside Conditions Outside Conditions RA Insulation Miscellaneous

Refuge Alternative User Input Template

Main Scrubber Data

[Entered as individual source(s) in separate row(s): e.g., in row 6, column 1]

Hanging CO2 scrubber material curtain (symbol X) OR

Number of rows of scrubbers along length: 2

Number of scrubbers in each row: 2

Single box-type CO2 scrubber on floor (=)
(Number of scrubbers is (1 x 1))

Contact surface with floor: 0.1 m2

Height in % of the RA height: 25.0 %

Outer Surface Area: 0.5 m2

Mass: 0.0 kg

Specific Heat: 1000.0 J/kg-K

Total Heat dissipation: 27.5 W

Percent of latent heat: 50 %

Scrubber Distribution Data

Index	X Position	Y Position	Surface Multiplier
1	2	0.6	1
2	2	2.3	1
3	4.5	0.6	1
4	4.5	2.3	1

RUN Open Location Save Location OK Cancel

RA Example: a 10-person RA with hanger-type CO₂ scrubber

The screenshot shows the 'Refuge Alternative' software interface. The window title is 'Refuge Alternative'. The menu bar includes 'File', 'Graph', and 'Reset'. Below the menu bar is a 'Select Template' dropdown. The main area is divided into several tabs: 'Room', 'HSE Data General', 'HSE Data Individual', 'Scrubber', 'Inside Conditions', 'Outside Conditions', 'RA Insulation', and 'Miscellaneous'. The 'HSE Data Individual' tab is active, displaying the 'Refuge Alternative User Input Template'.

The 'Individual Human/Scrubber/Equipment Data' table is shown below. It has columns for Index, X Position, Y Position, Surface Multiplier, Heat Dissipation Multiplier, and Moisture Dissipation Multiplier. The table contains 12 rows of data. Row 2 is highlighted in blue. A context menu is open over row 2, showing 'Enable' and 'Disable' options.

To the right of the table is a 2D layout of the room. The room is a light blue rectangle. There are 12 numbered circles representing occupants. Circles 1 and 2 are red, indicating they are disabled. Circles 3 through 12 are green. There are two yellow circles labeled 'HS' representing hanger scrubbers. A red button labeled 'Disable Occupant' is located above the layout. A red arrow points from the 'Disable Occupant' button to the text 'Toggles disable/Move Mode'. Another red arrow points from the 'Disable Occupant' button to the text 'Disabled sets all 3 Multipliers to 0'. A red arrow points from the 'Disable Occupant' button to the text 'Disabled items are red'. A red arrow points from the 'Enable' button in the context menu to the text 'Pressing enabled here will flick all Multipliers to 1'. A red arrow points from the 'Disable' button in the context menu to the text 'Pressing Disabled here will disable the occupant by setting all multipliers to 0'. A red arrow points from the 'HS' icon to the text 'Hanger Scrubber Icon Movable by Dragging just like the Occupants'.

The bottom of the interface has a toolbar with buttons for 'RUN', 'Open Location', 'Save Location', 'OK', and 'Cancel'.

Index	X Position	Y Position	Surface Multiplier	Heat Dissipation Multiplier	Moisture Dissipation Multiplier
1	0.39	0.66	0	0	0
2	0.39	1.98	0	0	0
3	1.16	0.66	1	1	1
4	1.32	1.77	1	1	1
5	1.83	0.86	1	1	1
6	1.93	1.98	1	1	1
7	2.71	0.66	1	1	1
8	2.71	1.98	1	1	1
9	3.48	0.66	1	1	1
10	3.48	1.98	1	1	1
11	4.25	0.66	1	1	1
12	4.25	1.98	1	1	1

Toggles disable/Move Mode

Disabled sets all 3 Multipliers to 0

Disabled items are red

Pressing enabled here will flick all Multipliers to 1

Pressing Disabled here will disable the occupant by setting all multipliers to 0

Hanger Scrubber Icon Movable by Dragging just like the Occupants

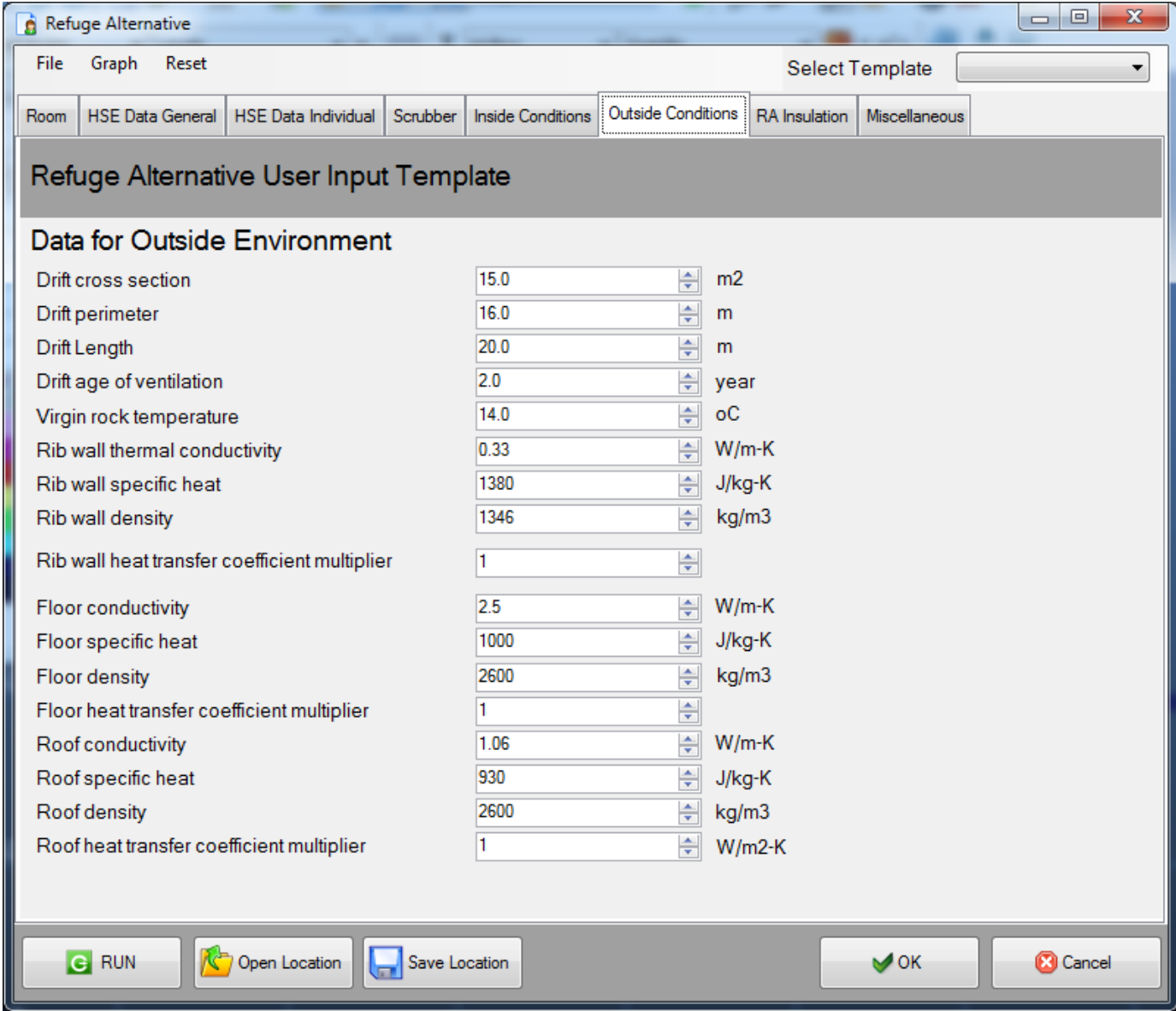
Data input tab for the RA in the GUI

The screenshot shows a software window titled "Refuge Alternative" with a menu bar (File, Graph, Reset) and a "Select Template" dropdown. The "Inside Conditions" tab is active, displaying input fields for initial conditions inside and outside the RA. The "Initial Conditions Inside the RA" section includes fields for Air temperature (14.0 °C), Air humidity (0.0 %), and Barometric pressure at RA floor level (100000 Pa). The "Initial Conditions Outside the RA" section includes fields for Air temperature (14.0 °C), Air relative humidity (0.0 %), Air velocity (2.0 m/s), and three surface temperature fields (Rib, Floor, and Roof steady-state surface temperature, all at 14.0 °C). The bottom of the window features buttons for RUN, Open Location, Save Location, OK, and Cancel.

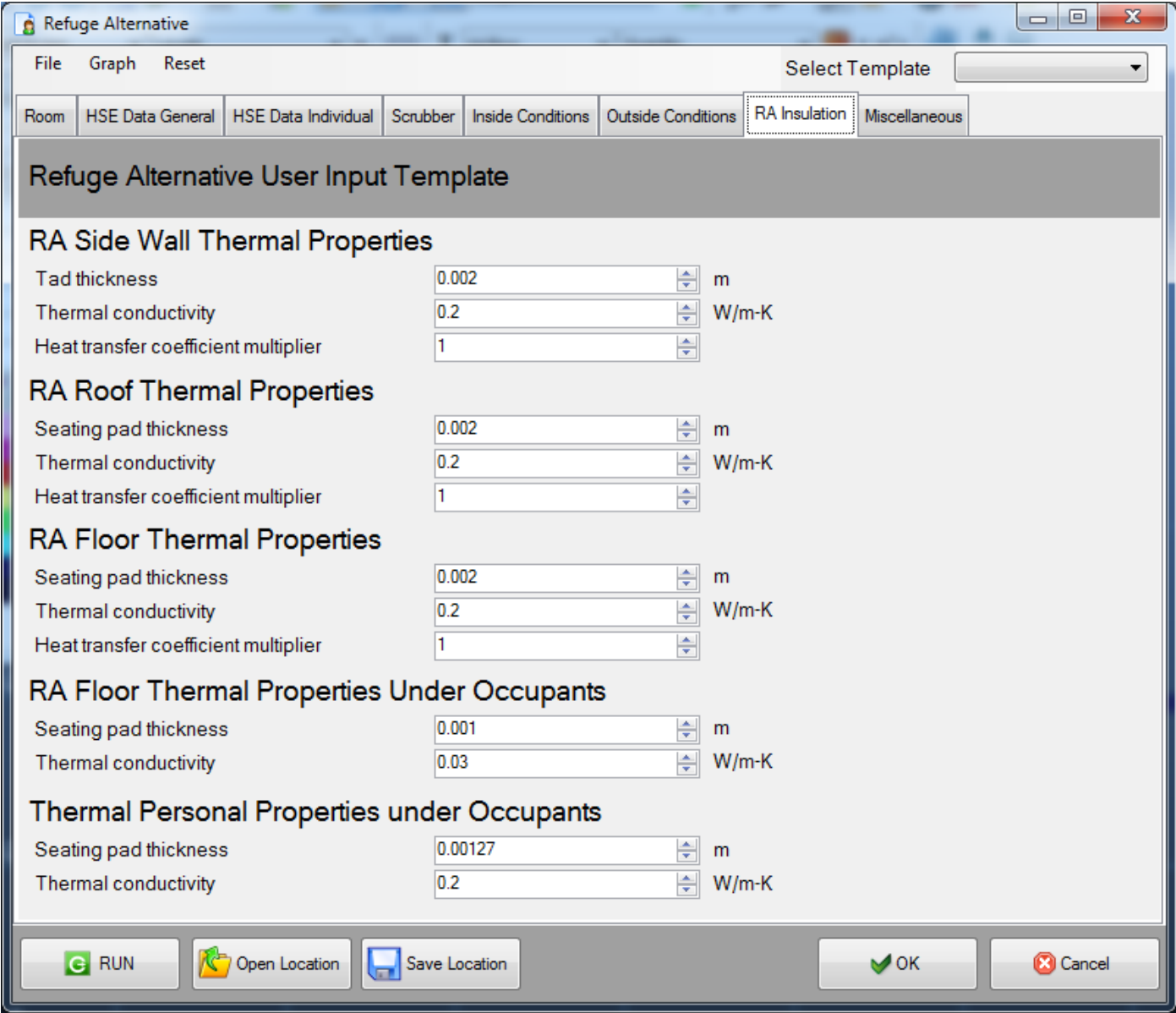
Initial Conditions Inside the RA		
Air temperature	14.0	°C
Air humidity	0.0	%
Barometric pressure at RA floor level	100000	Pa

Initial Conditions Outside the RA		
Air temperature	14.0	°C
Air relative humidity	0.0	%
Air velocity	2.0	m/s
Initial steady state air temperature	14.0	°C
Rib steady-state surface temperature	14.0	°C
Floor steady-state surface temperature	14.0	°C
Roof steady-state surface temperature	14.0	°C

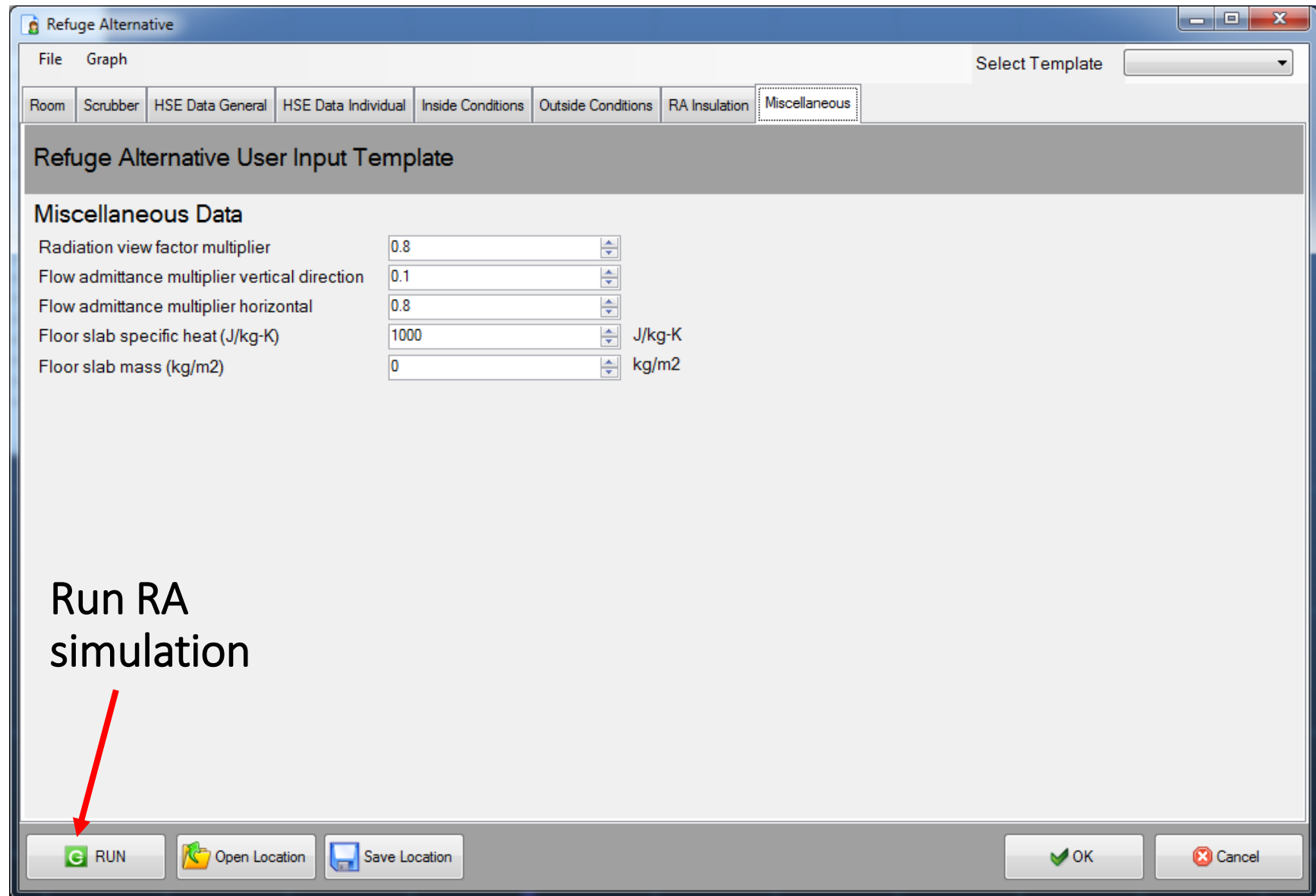
Data input tab for RA from within the GUI



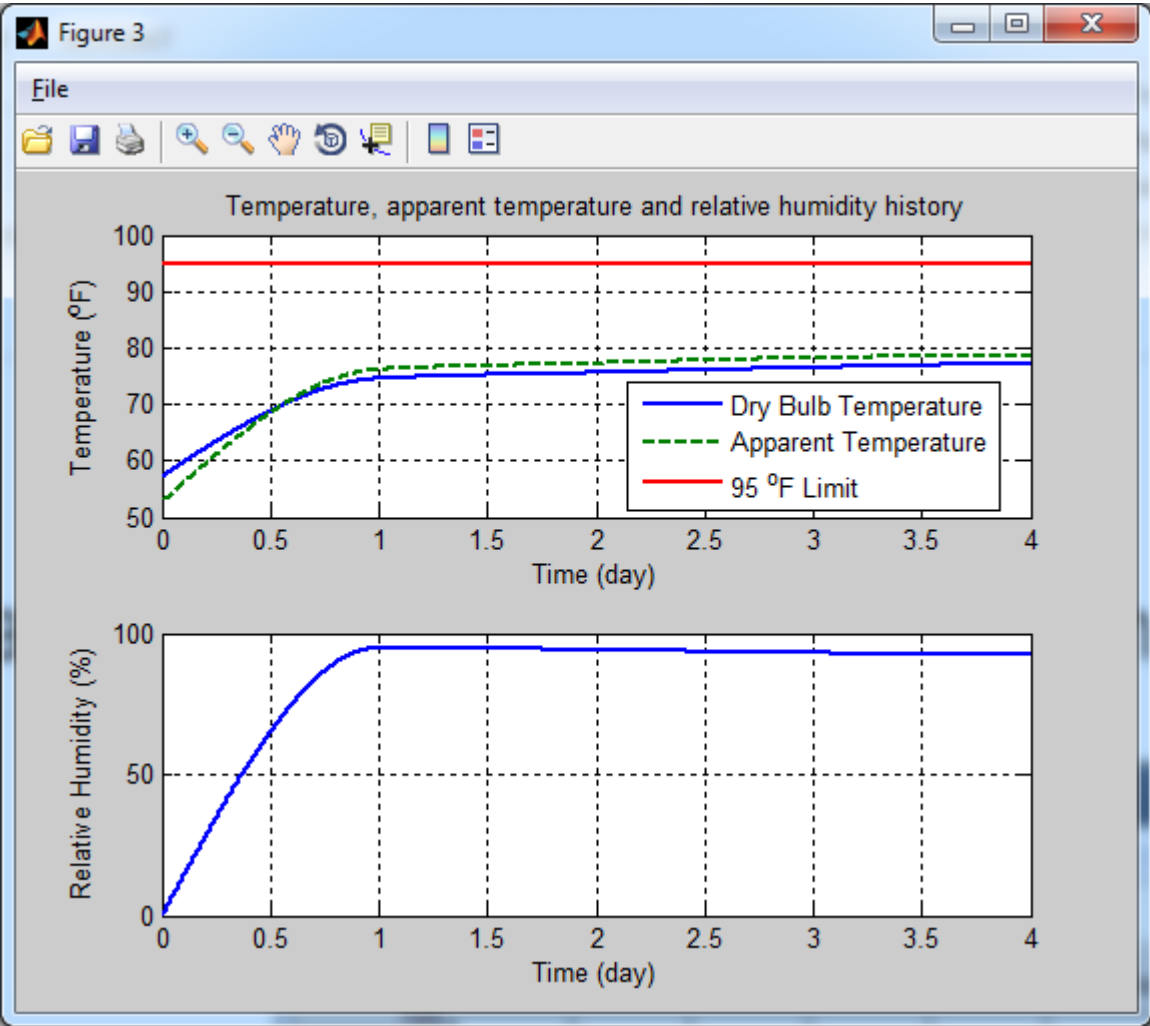
Data input tab for RA from within the GUI



Data input tab for the RA in the GUI

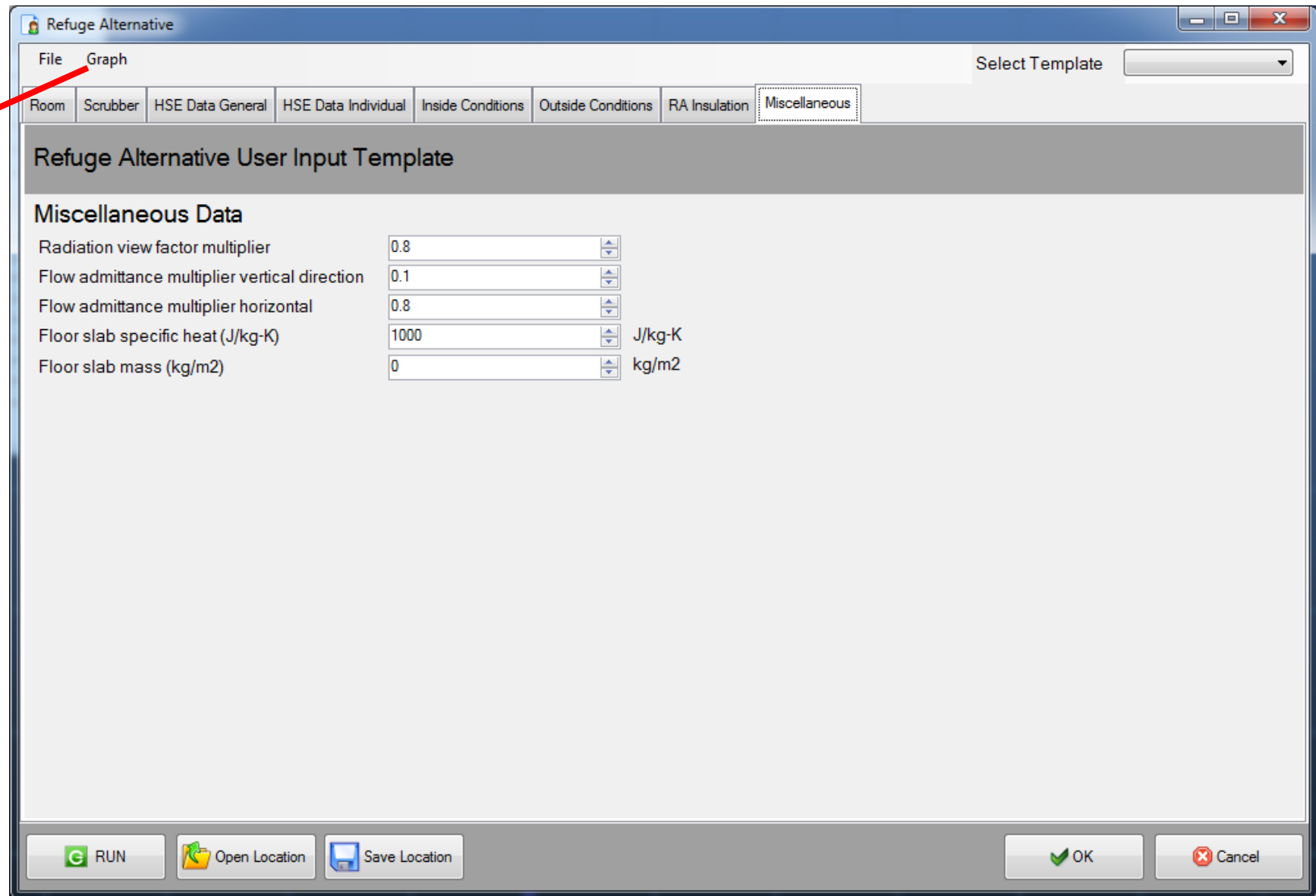
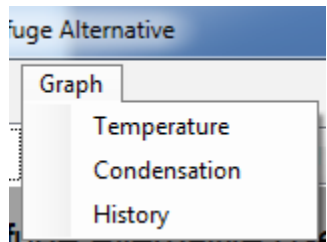


Temperature history plot upon successful completion of simulation



Data input tab for RA from within the GUI

Graph menu options

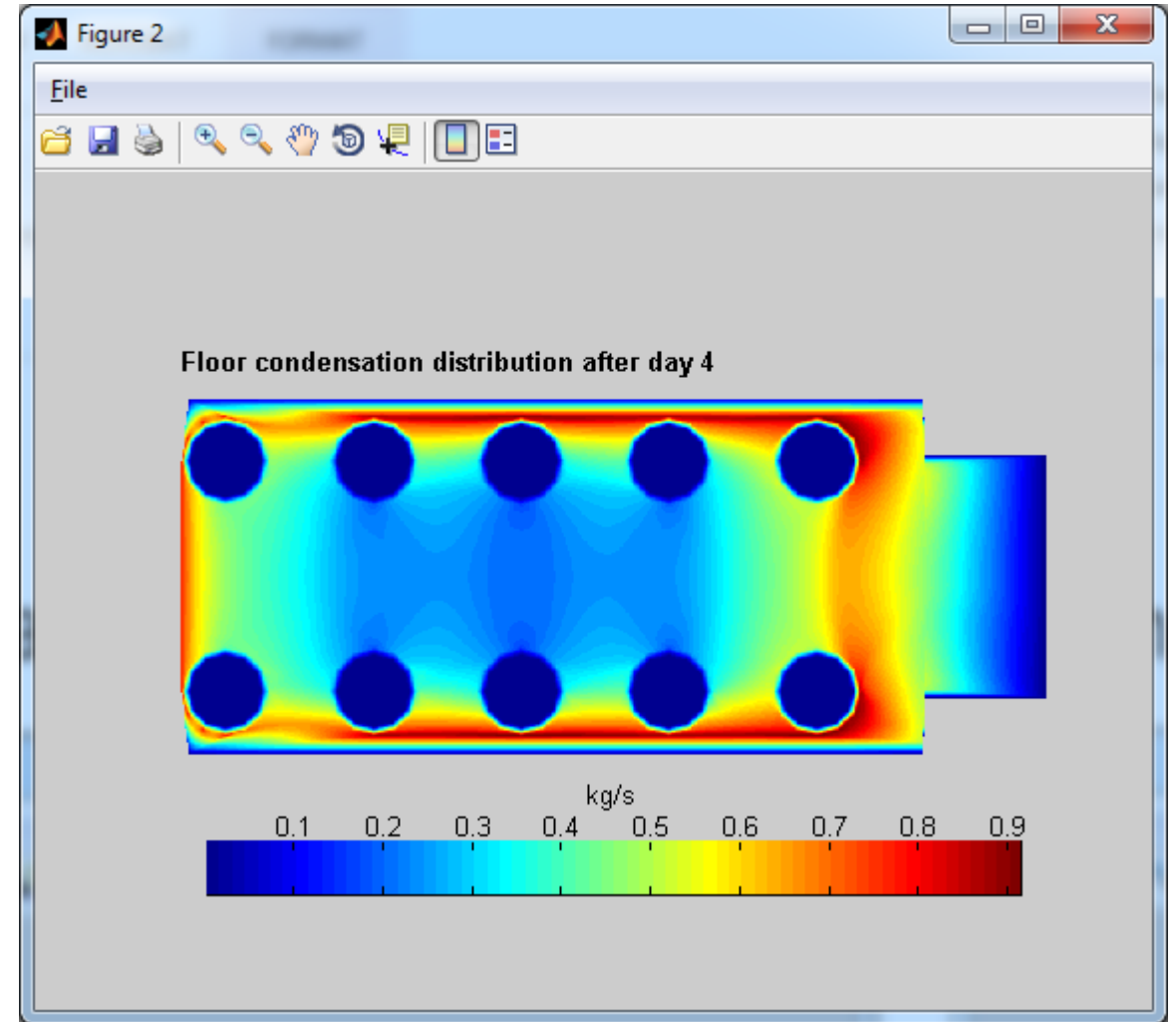
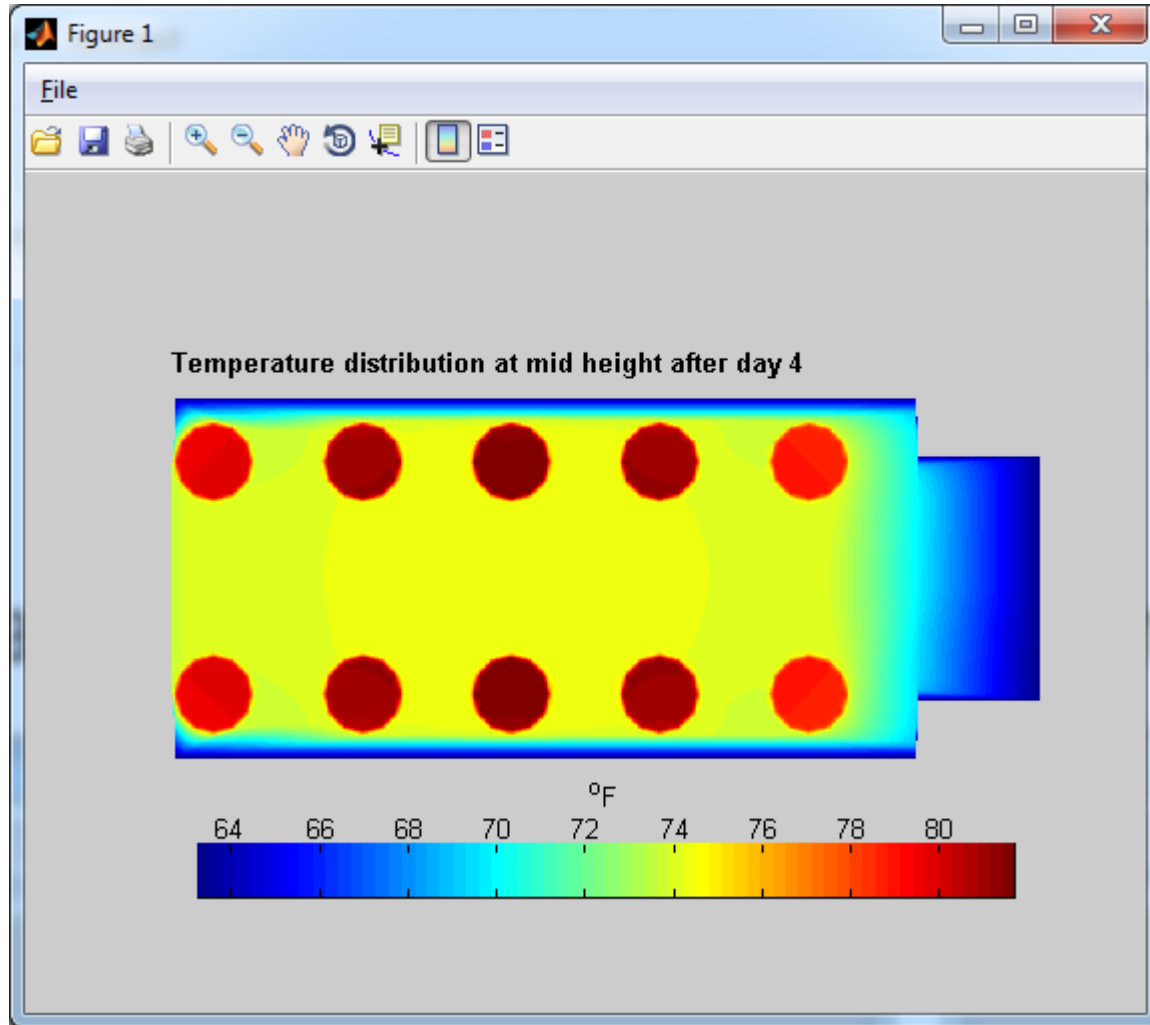


The screenshot shows the 'Refuge Alternative' application window. The 'Miscellaneous' tab is selected, displaying the 'Refuge Alternative User Input Template' for 'Miscellaneous Data'. The data is entered into spinners for various parameters.

Parameter	Value	Unit
Radiation view factor multiplier	0.8	
Flow admittance multiplier vertical direction	0.1	
Flow admittance multiplier horizontal	0.8	
Floor slab specific heat (J/kg-K)	1000	J/kg-K
Floor slab mass (kg/m ²)	0	kg/m ²

At the bottom of the window, there are buttons for 'RUN', 'Open Location', 'Save Location', 'OK', and 'Cancel'.

More results for the 10-person RA, uniform distribution of occupants, hanger-type CO₂ scrubber



Temperature and condensation distribution maps

Results of RA examples

Example 1: 10-person RA, uniform distribution of occupants, hanger-type CO₂ scrubber, 57.2 °F ambient temperature (repeated)

The screenshot displays the 'Refuge Alternative' software interface. The window title is 'Refuge Alternative'. The menu bar includes 'File', 'Graph', and 'Reset'. A 'Select Template' dropdown menu is visible. Below the menu bar are several tabs: 'Room', 'HSE Data General', 'HSE Data Individual' (which is selected), 'Scrubber', 'Inside Conditions', 'Outside Conditions', 'RA Insulation', and 'Miscellaneous'. The main area is titled 'Refuge Alternative User Input Template' and contains an 'Auto Position' button. Below this is the 'Individual Human/Scrubber/Equipment Data' section, which includes a table with the following data:

Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
1	0.3	0.51	1	1
2	0.3	2.39	1	1
3	1.51	0.51	1	1
4	1.51	2.39	1	1
5	2.71	0.51	1	1
6	2.71	2.39	1	1
7	3.91	0.51	1	1
8	3.91	2.39	1	1
9	5.12	0.51	1	1
10	5.12	2.39	1	1

To the right of the table is a 2D layout of a rectangular area with a light blue background. Ten green circles, numbered 1 through 10, are arranged in two vertical columns of five. The circles are positioned to correspond to the X and Y coordinates in the table above. The bottom of the interface features a toolbar with buttons for 'RUN', 'Open Location', 'Save Location', 'OK', and 'Cancel'.

Example 1: 10-person RA, uniform distribution of occupants, hanger-type CO₂ scrubber, 57.2 °F ambient temperature (repeated)

Refuge Alternative

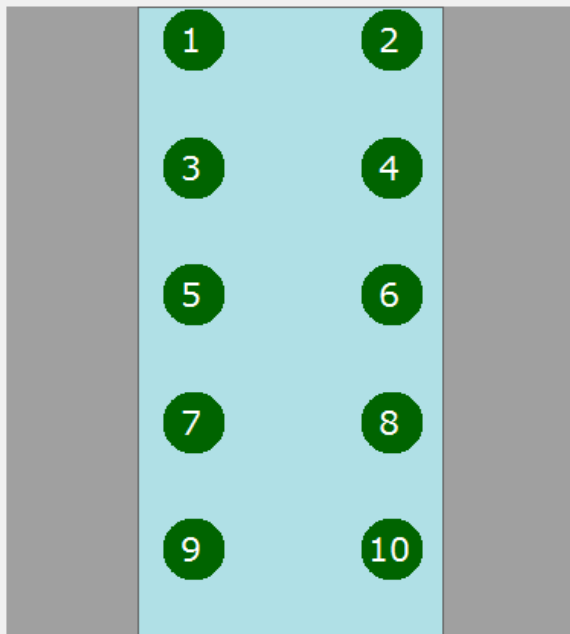
File Graph Reset Select Template

Room HSE Data General HSE Data Individual Scrubber Inside Conditions Outside Conditions RA Insulation Miscellaneous

Refuge Alternative User Input Template Auto Position

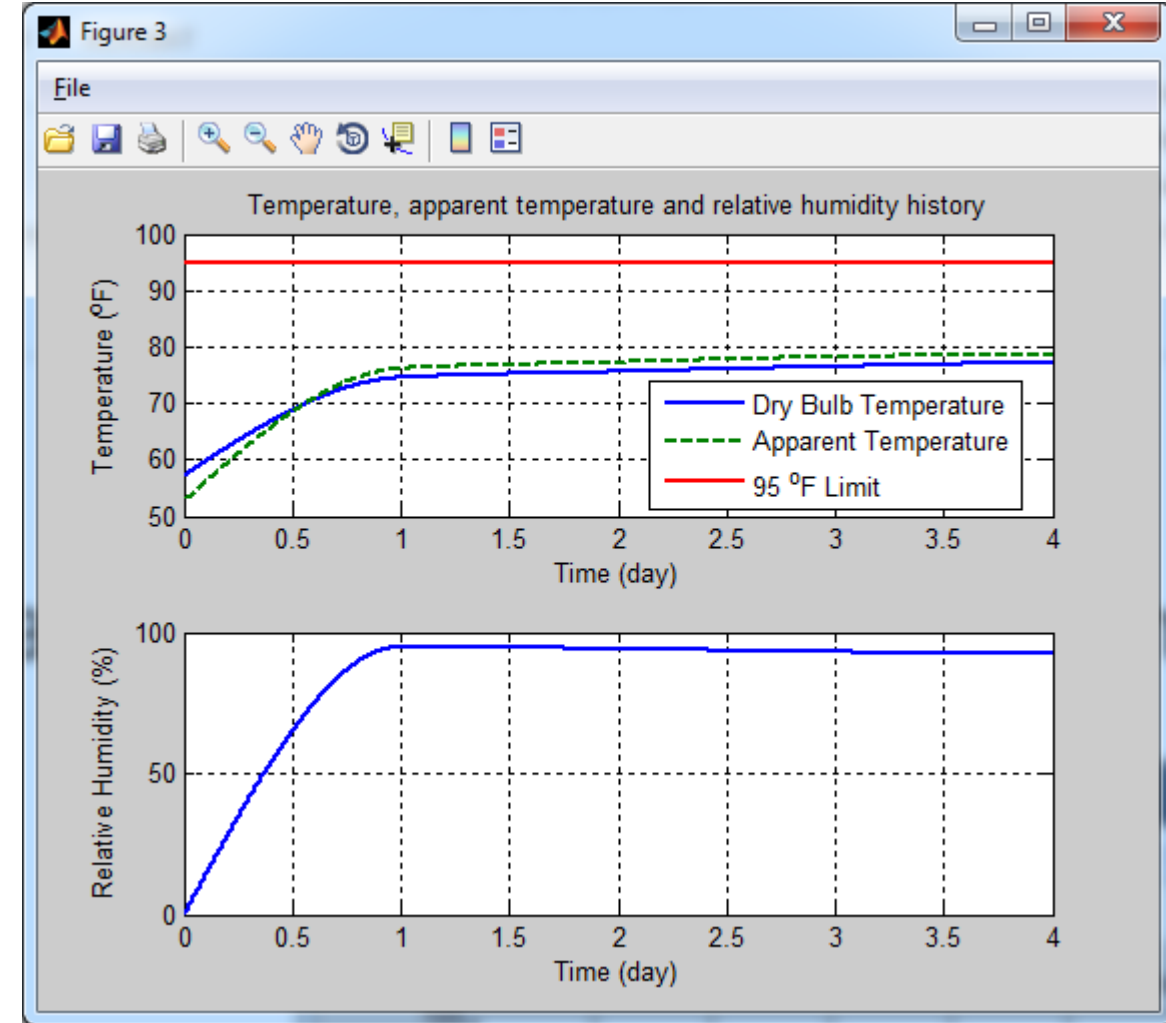
Individual Human/Scrubber/Equipment Data

Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
1	0.3	0.51	1	1
2	0.3	2.39	1	1
3	1.51	0.51	1	1
4	1.51	2.39	1	1
5	2.71	0.51	1	1
6	2.71	2.39	1	1
7	3.91	0.51	1	1
8	3.91	2.39	1	1
9	5.12	0.51	1	1
10	5.12	2.39	1	1



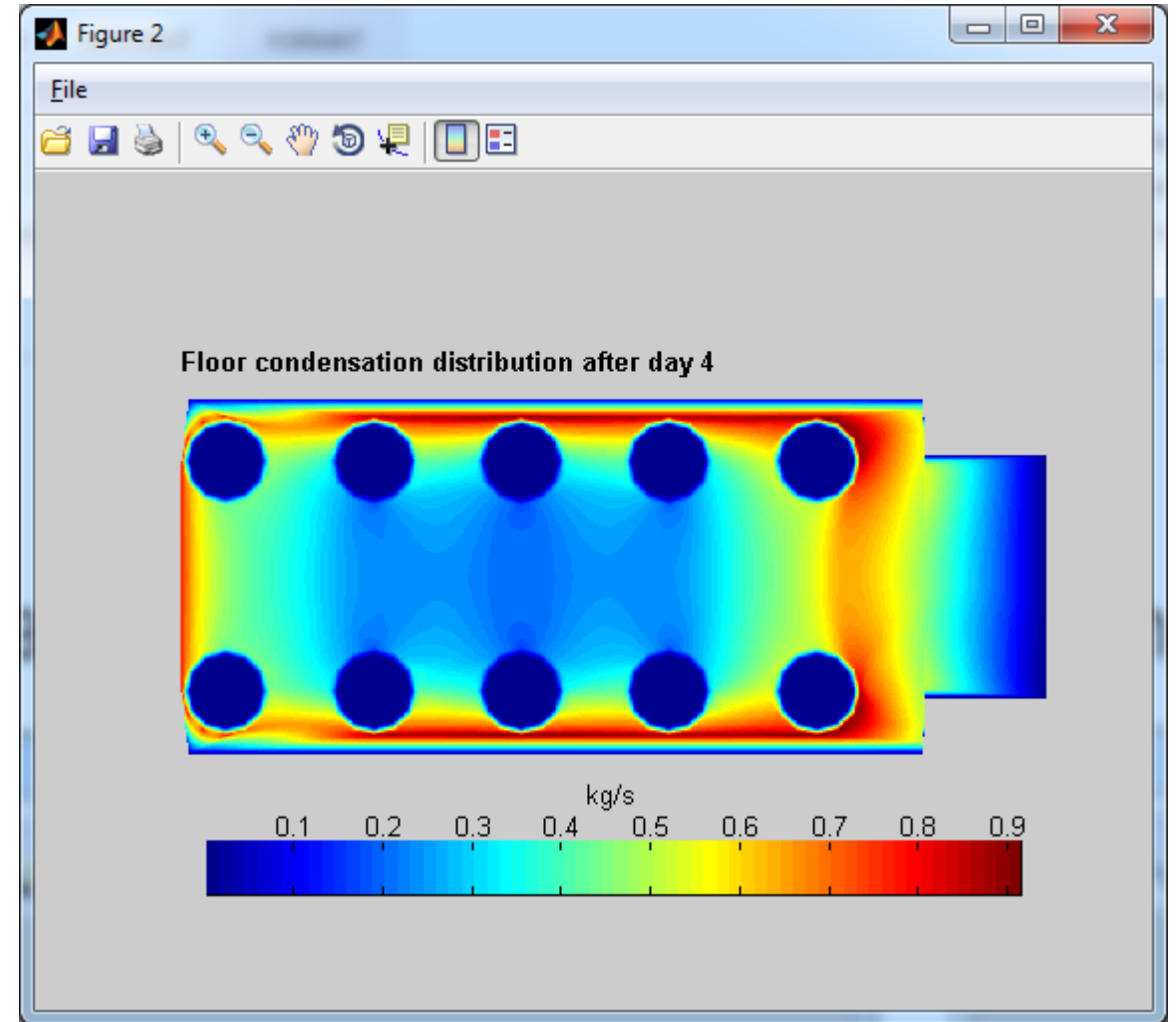
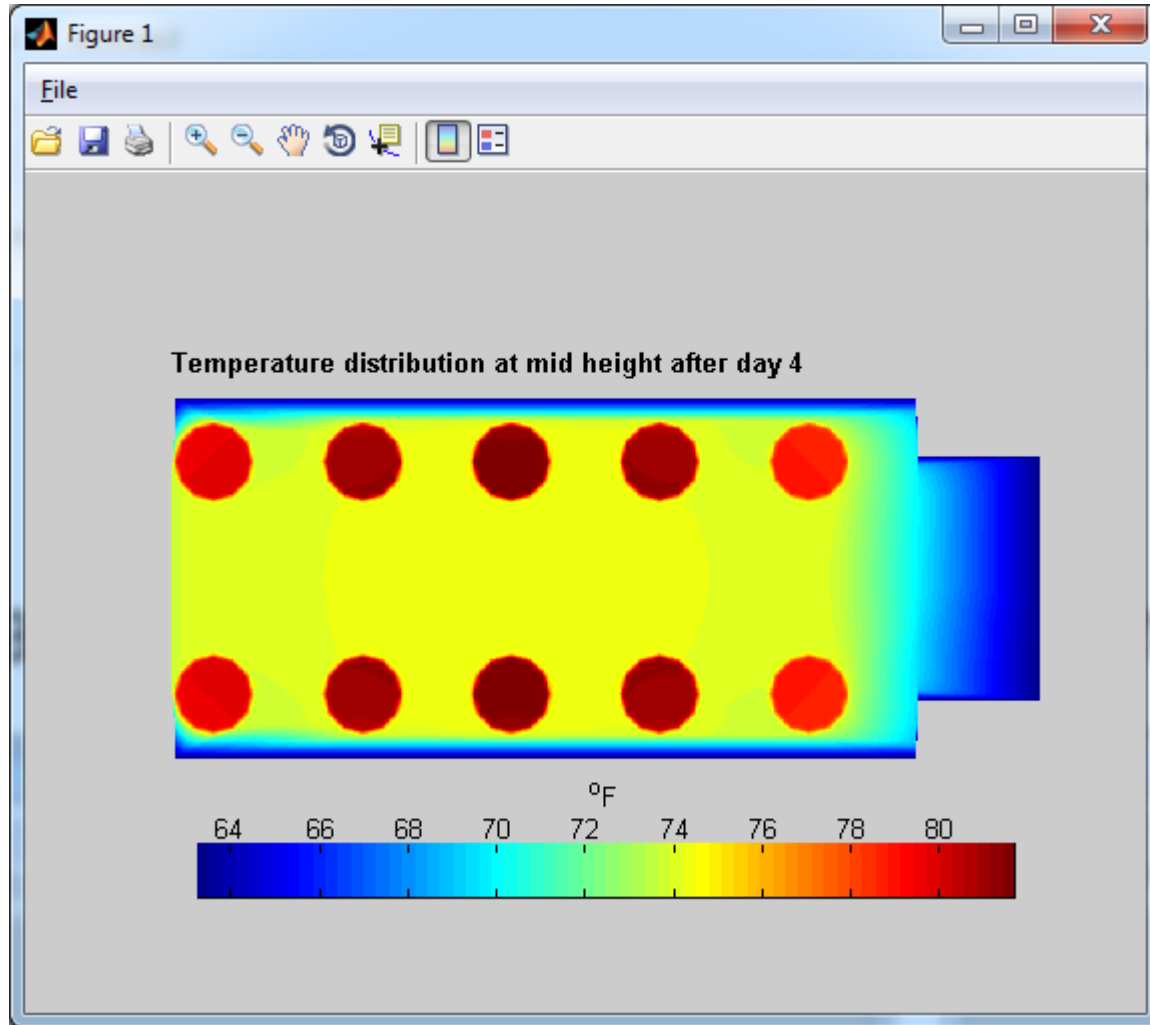
Y---->

RUN Open Location Save Location OK Cancel



Temperature and humidity vs. time

Example 1: 10-person RA, uniform distribution of occupants, hanger-type CO₂ scrubber (repeated)



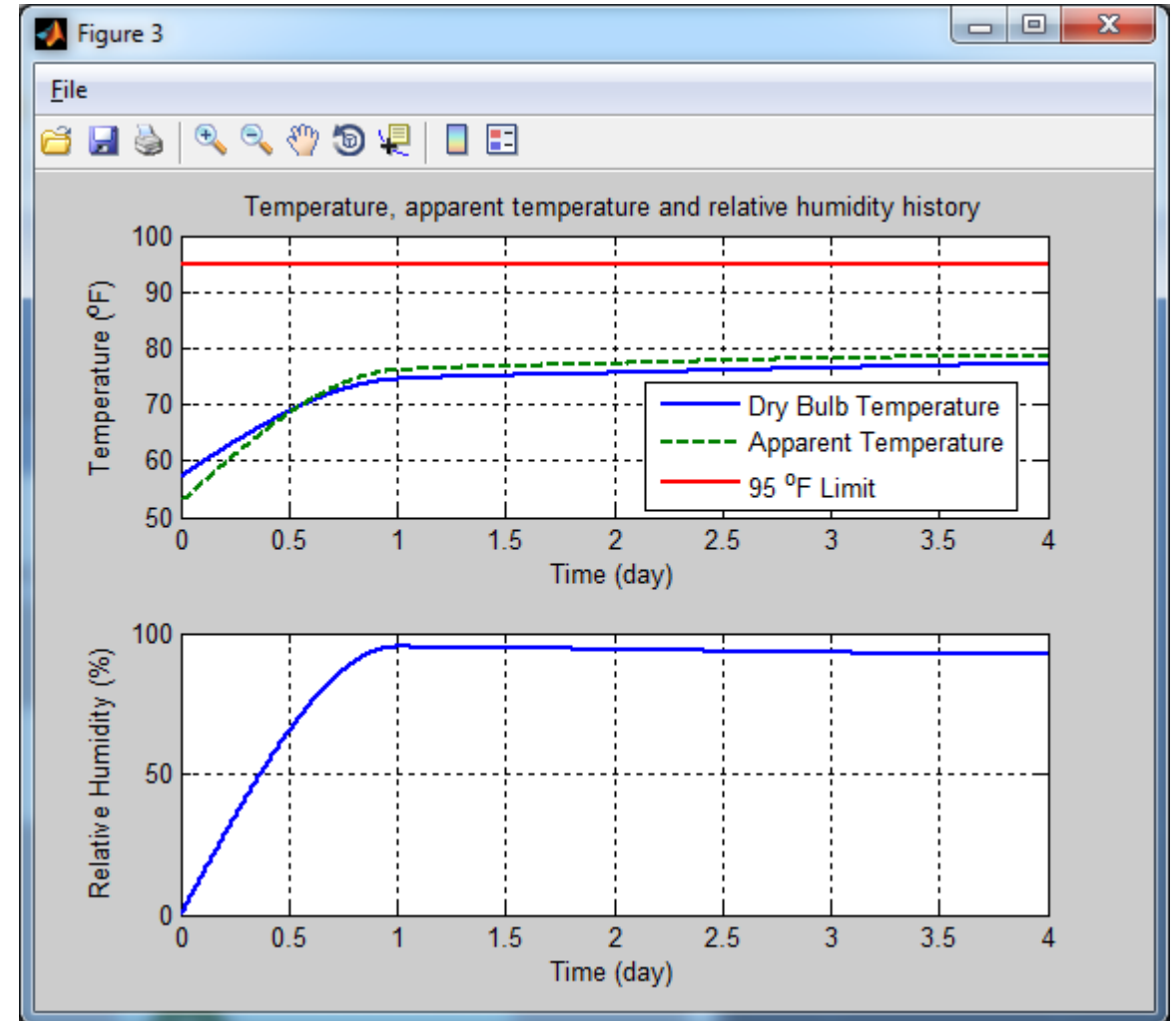
Temperature and condensation distribution maps

Example 2: 10-person RA, non-uniform distribution of occupants, hanger-type CO₂ scrubber, 57.2 °F ambient temperature

Manually moved occupants, other parameters unchanged

The screenshot shows the 'Refuge Alternative' software interface. The 'Individual Human/Scrubber/Equipment Data' table is visible, listing 10 occupants with their respective X and Y positions. To the right of the table is a 2D layout of the refuge, represented by a light blue rectangle, with 10 green circles numbered 1 through 10 indicating the positions of the occupants. The circles are arranged in two columns: the left column contains circles 1, 3, 5, 7, and 9; the right column contains circles 2, 4, 6, 8, and 10.

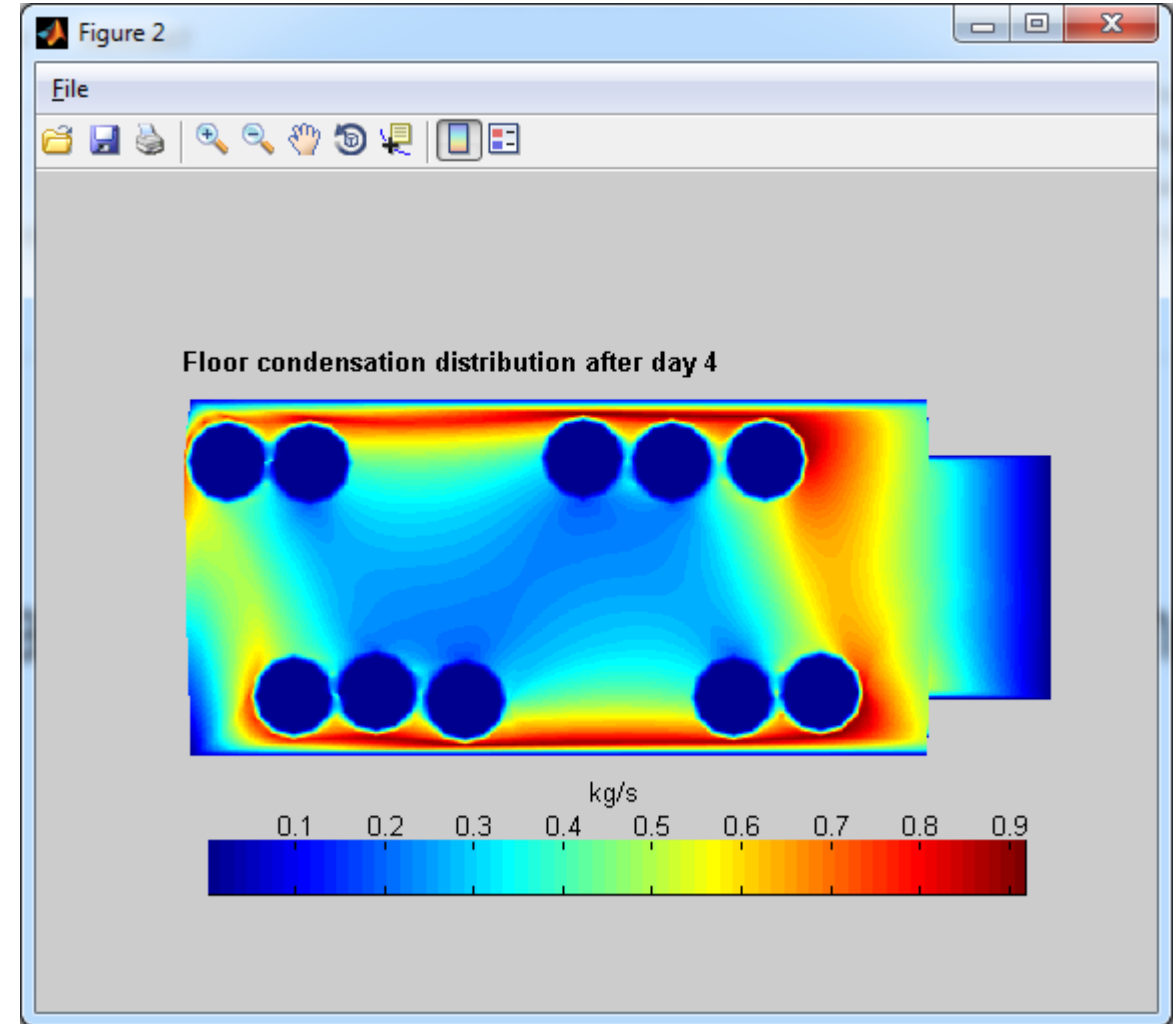
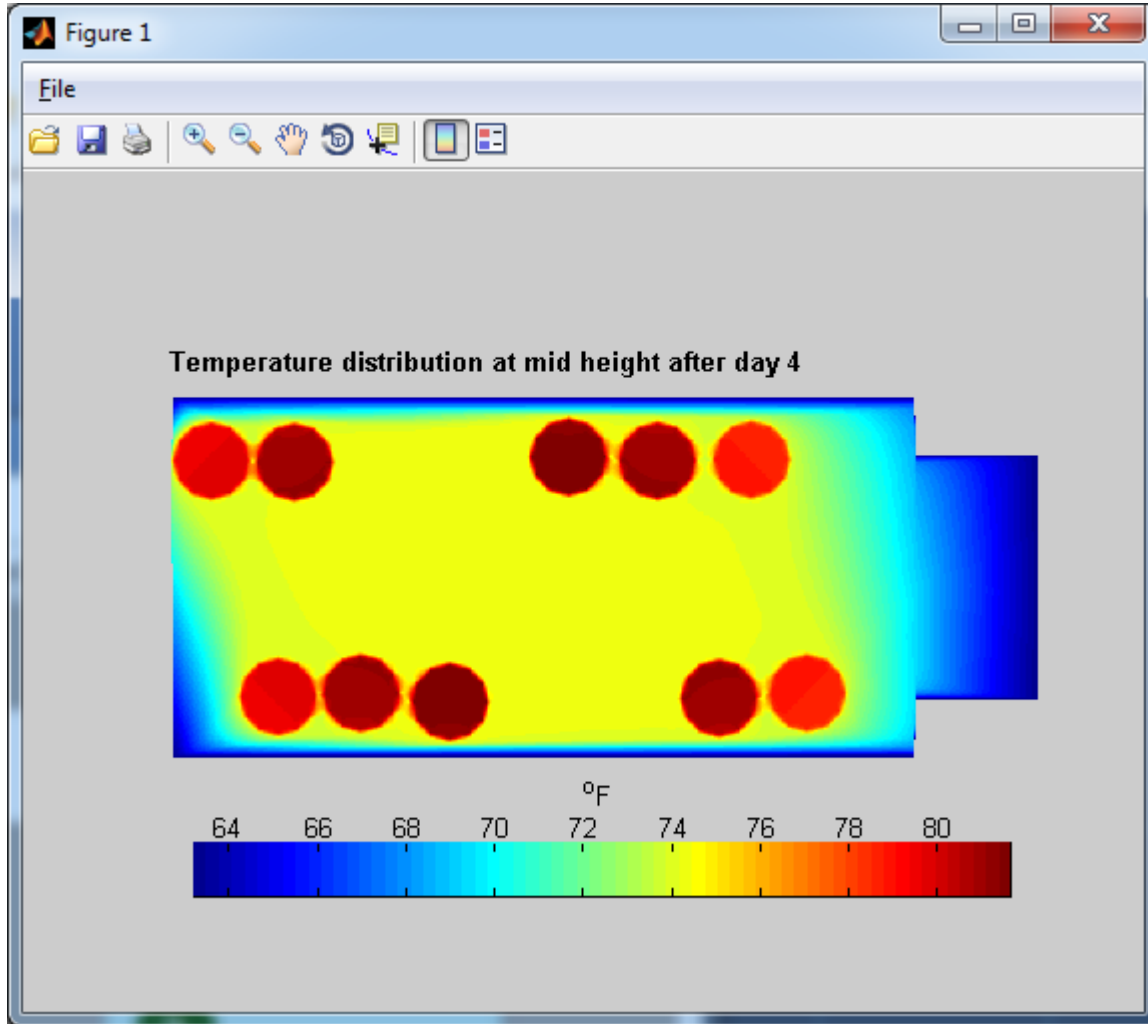
Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
1	0.84	0.48	1	1
2	0.3	2.39	1	1
3	1.51	0.51	1	1
4	0.97	2.38	1	1
5	2.23	0.44	1	1
6	3.19	2.42	1	1
7	4.41	0.47	1	1
8	3.91	2.39	1	1
9	5.12	0.51	1	1
10	4.67	2.40	1	1



Temperature and humidity vs. time

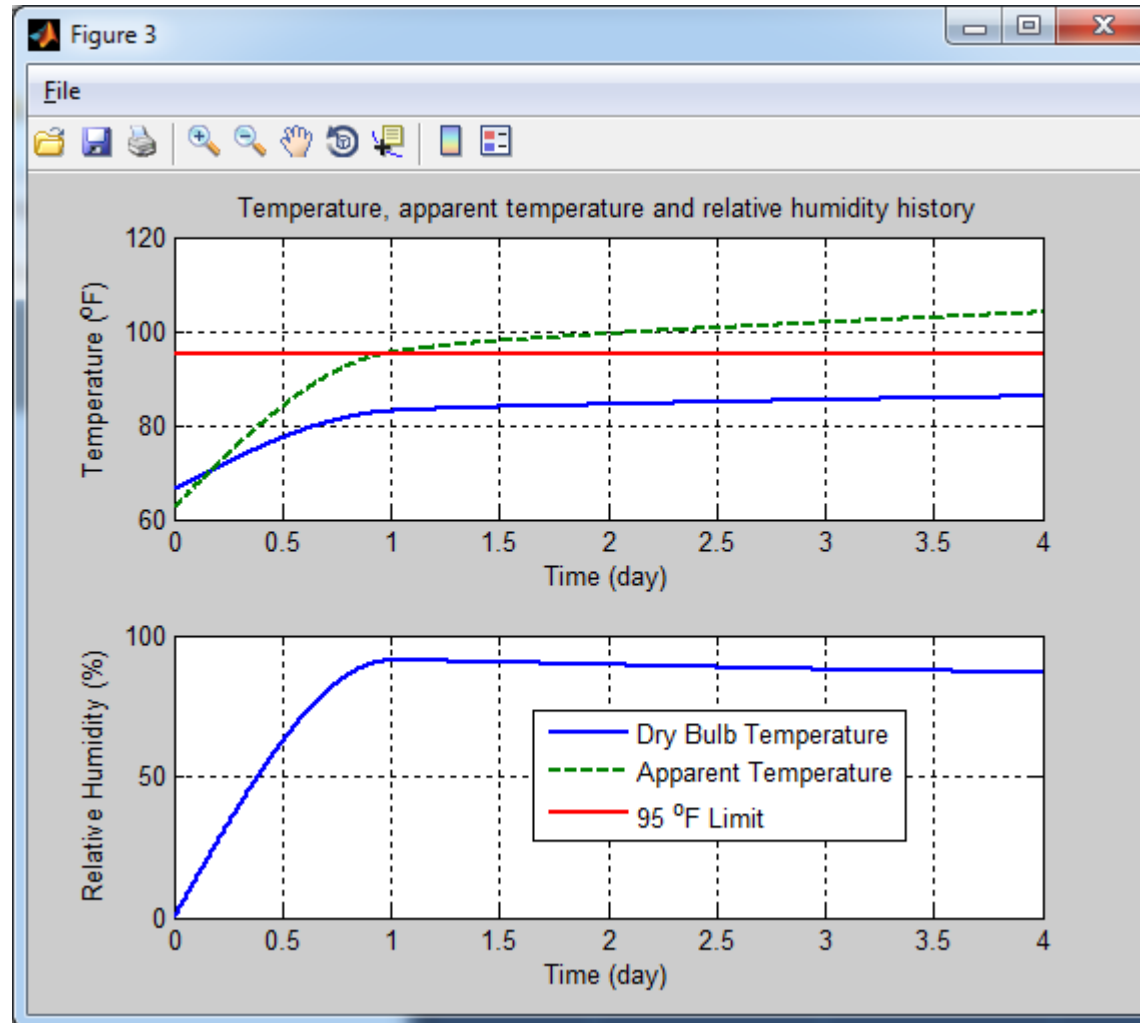
Example 2: 10-person RA, non-uniform distribution of occupants,
hanger-type CO₂ scrubber, 57.2 °F ambient temperature

Manually moved occupants



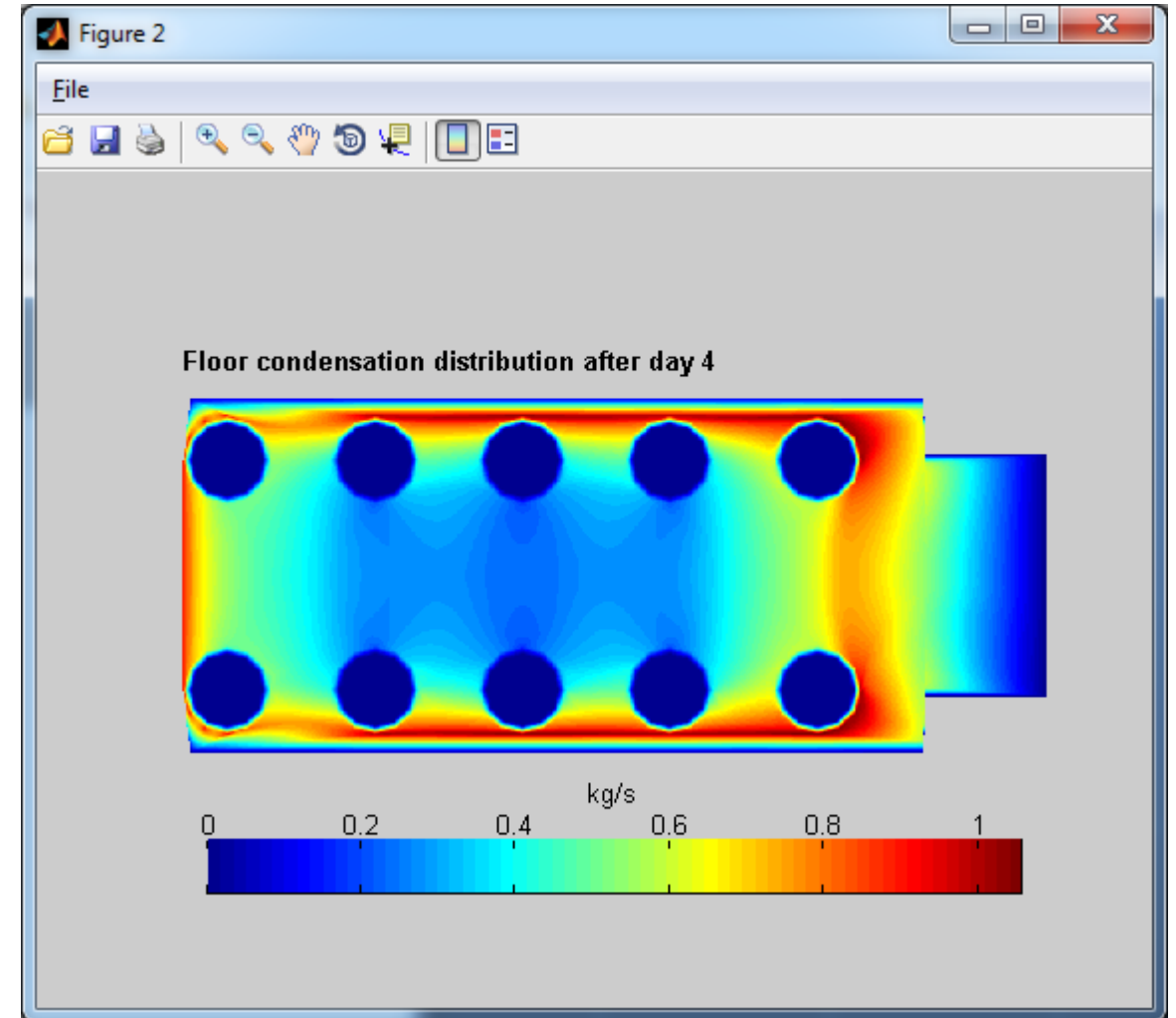
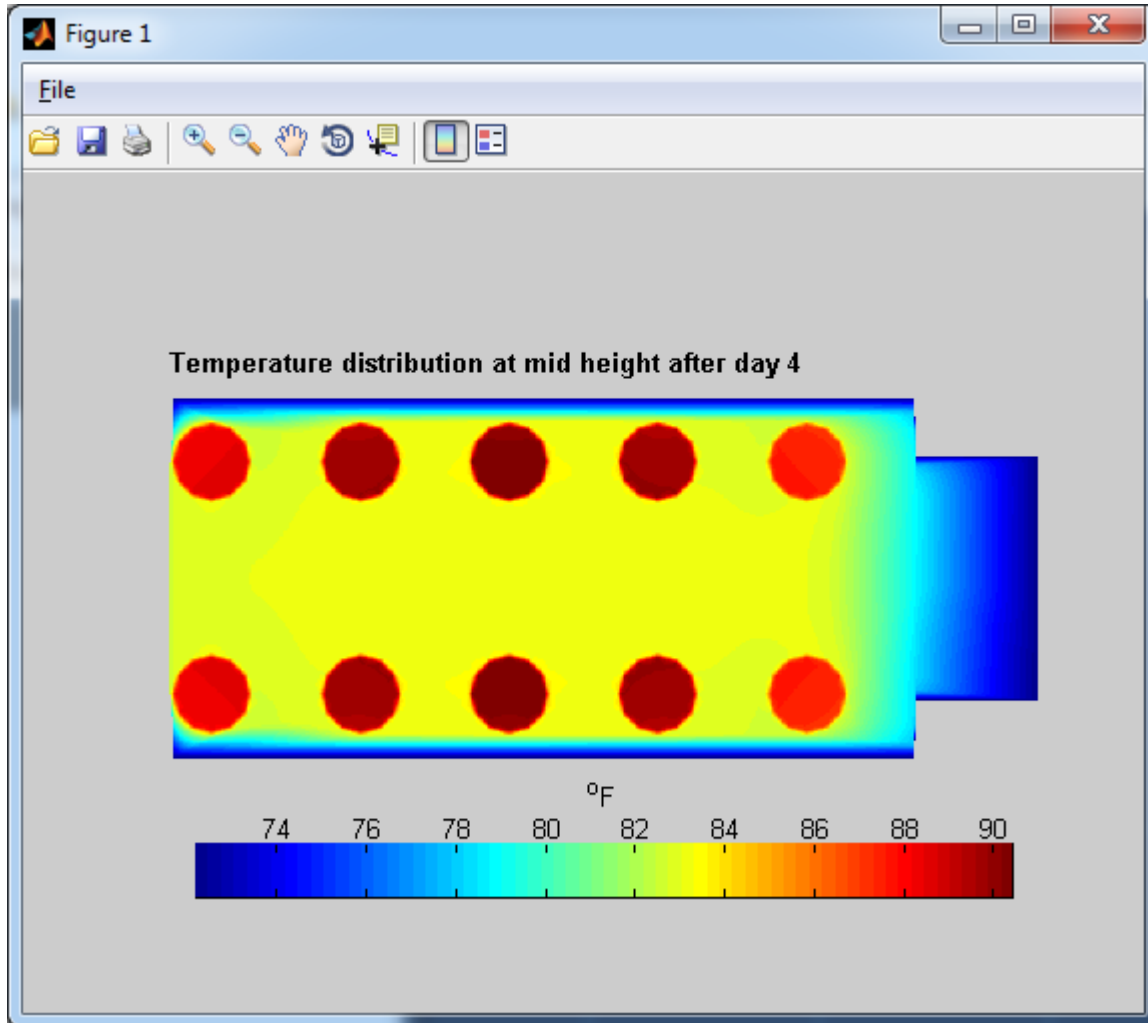
Temperature and condensation distribution maps

Example 3: 10-person RA, uniform distribution of occupants,
hanger-type CO₂ scrubber, 66.2°F ambient temperature
The RA is not in compliance, Ta > 95°F



Temperature and humidity vs. time

Example 3: 10-person RA, uniform distribution of occupants,
hanger-type CO₂ scrubber, 66.2°F ambient temperature
The RA is not in compliance, $T_a > 95^\circ\text{F}$



Temperature and condensation distribution maps

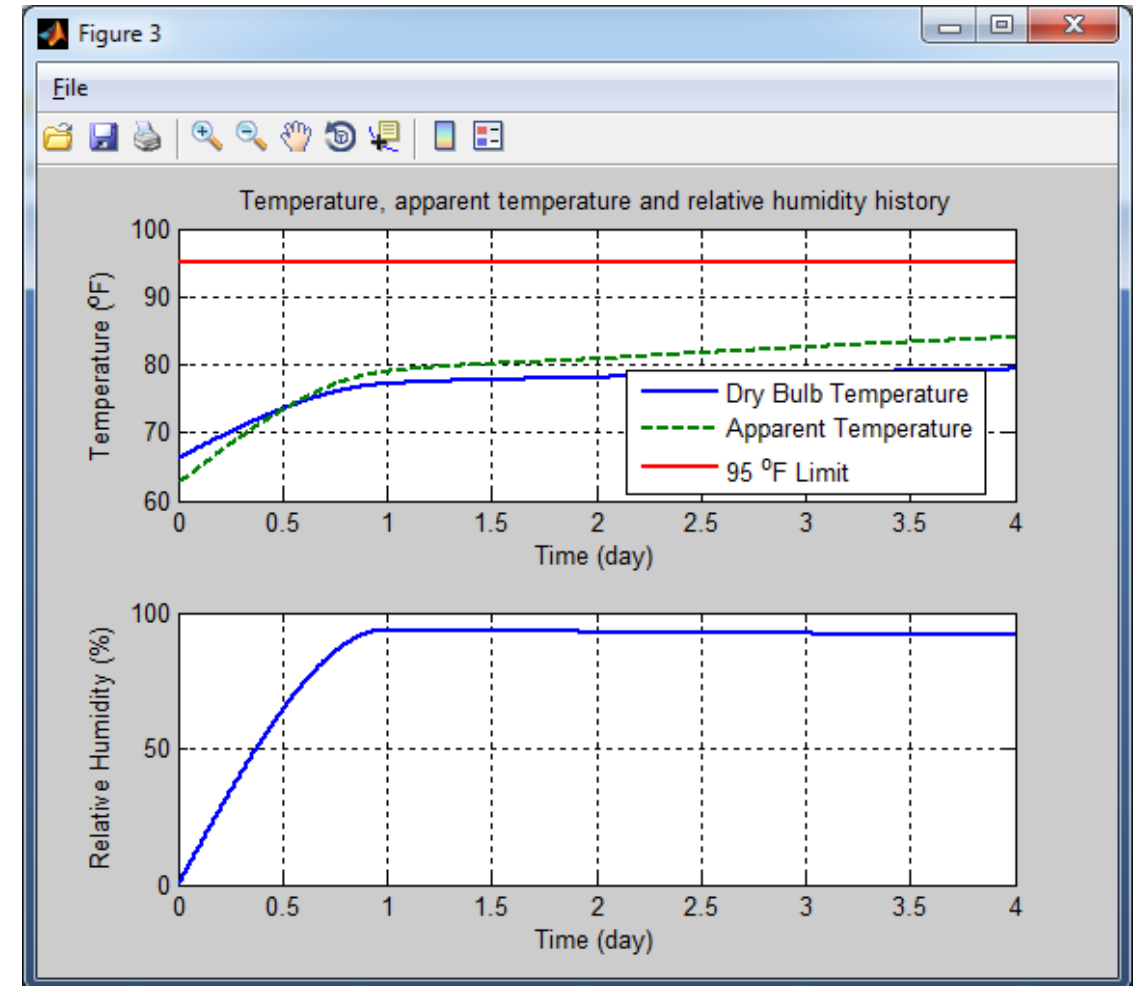
Example 4: 10-person RA, derated to 7-person occupancy, hanger-type CO₂ scrubber, 66.2°F ambient temperature

Reduced occupancy (10 to 7) from one side of RA space

Refuge Alternative User Input Template

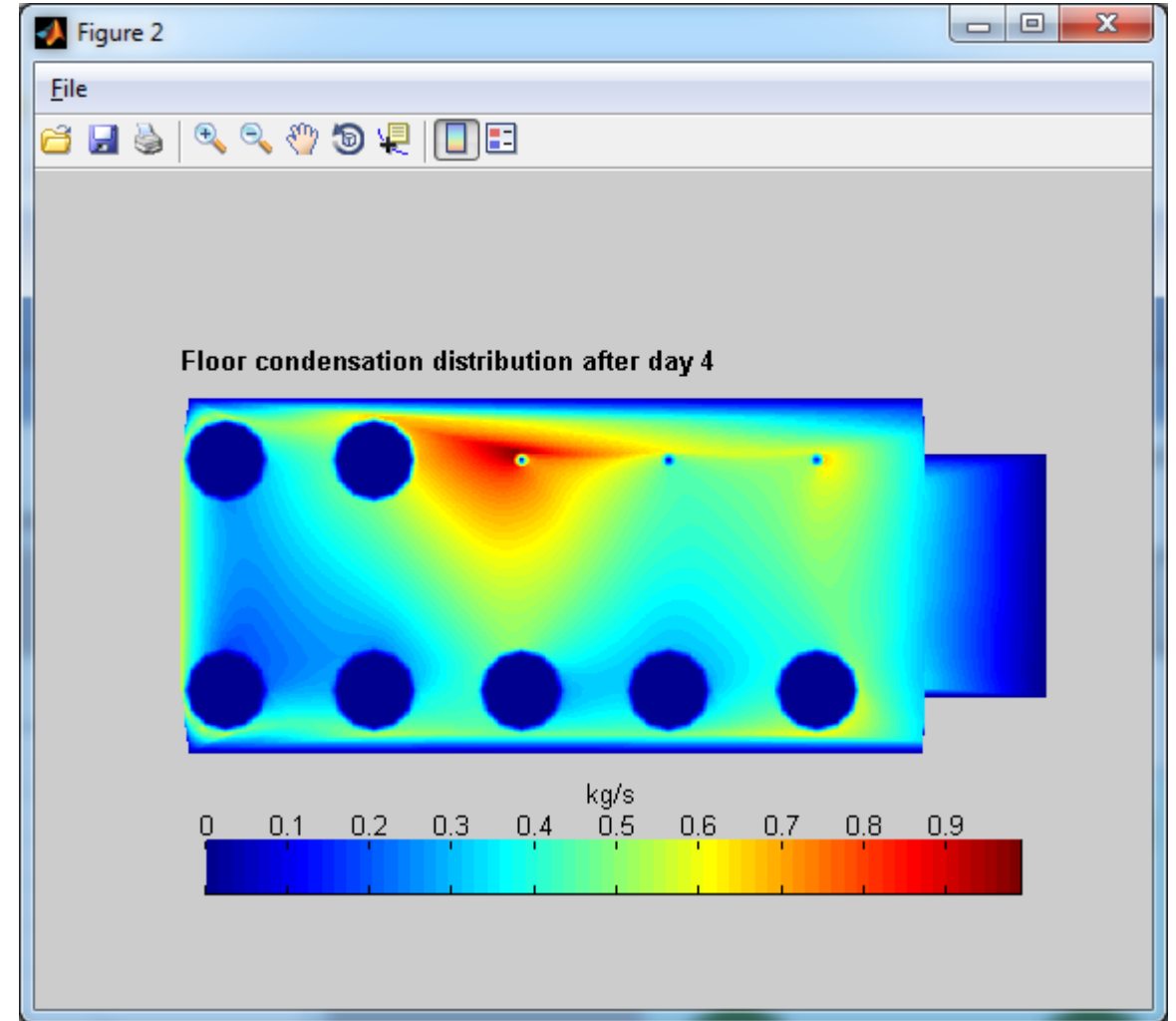
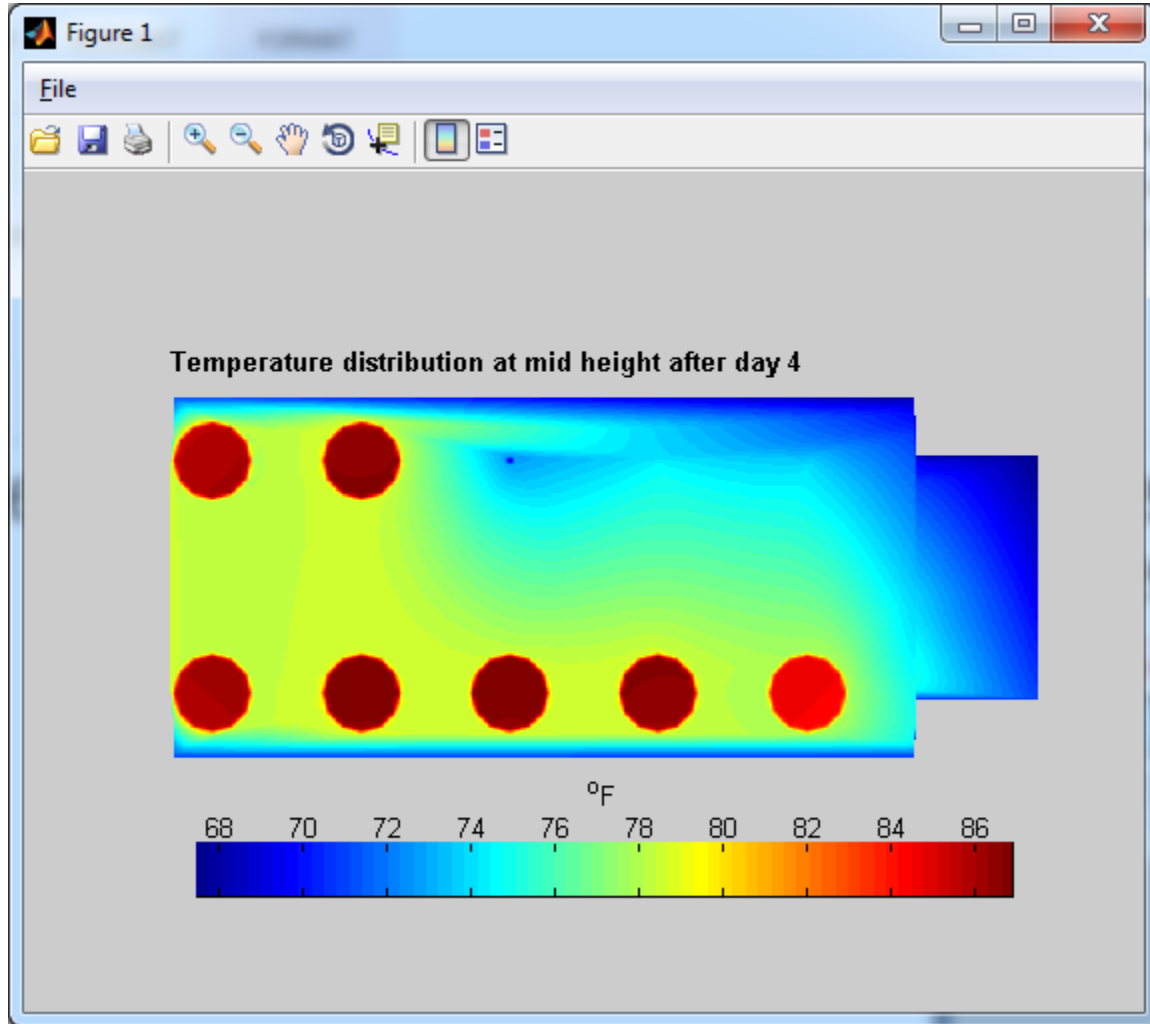
Index	X Position	Y Position	Surface Multiplier	Heat Dissipation Multiplier	Moisture Dissipation Multiplier
1	0.3	0.51	1	1	1
2	0.3	2.39	1	1	1
3	1.51	0.51	1	1	1
4	1.51	2.39	1	1	1
5	2.71	0.51	1	1	1
6	2.71	2.39	0	0	0
7	3.91	0.51	1	1	1
8	3.91	2.39	0	0	0
9	5.12	0.51	1	1	1
10	5.12	2.39	0	0	0

Note the zero multipliers are used to delete 3 occupants



Temperature and humidity vs. time

Example 4: 10-person RA, derated to 7-person occupancy, hanger-type CO₂ scrubber, 66.2°F ambient temperature
Reduced occupancy from one side of RA space



Temperature and condensation distribution maps

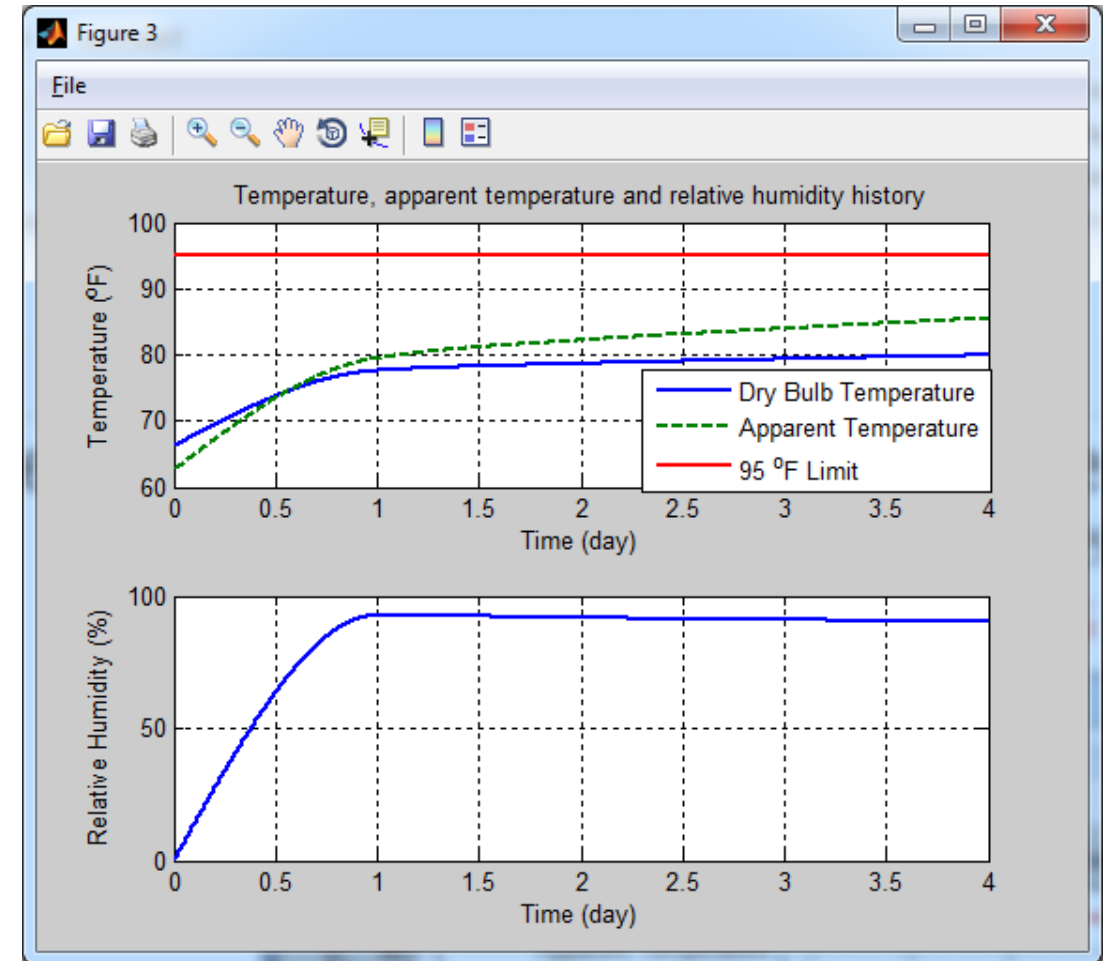
Example 5: 10-person RA, derated to 7-person occupancy, hanger-type CO₂ scrubber, 66.2°F ambient temperature

Reduced occupancy (10 to 7) from one end of RA space

Refuge Alternative User Input Template

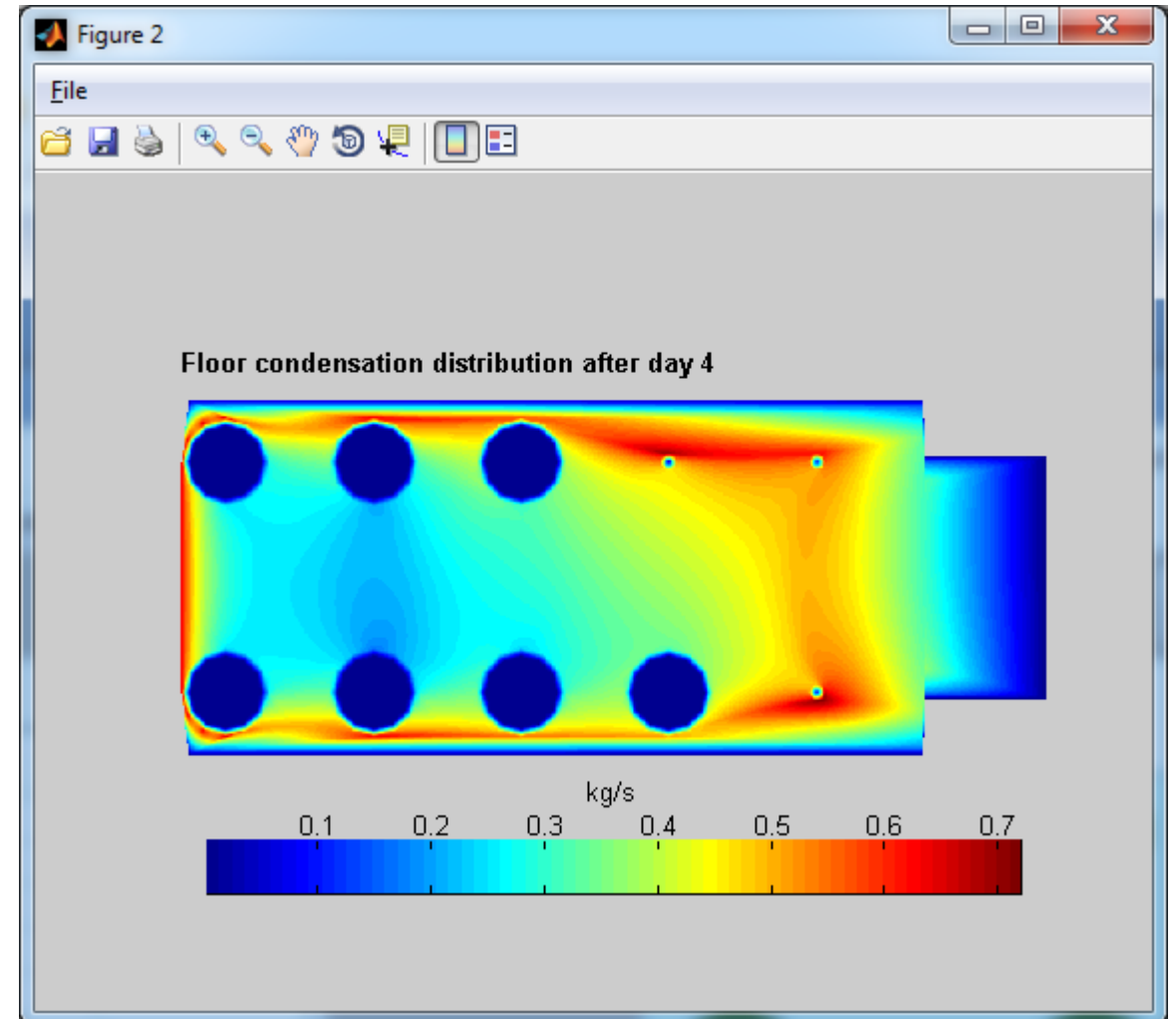
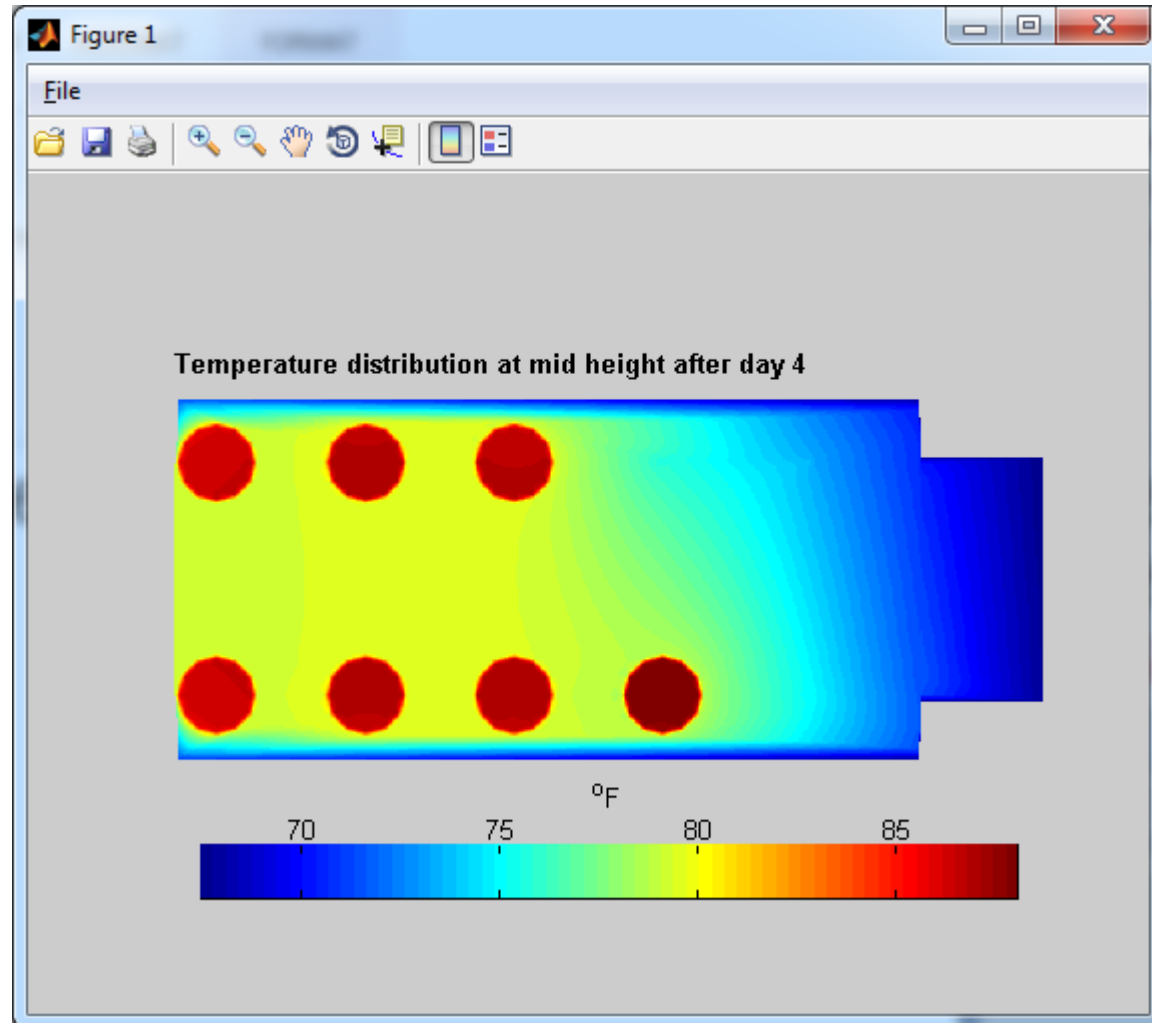
Index	X Position	Y Position	Surface Multiplier	Heat Dissipation Multiplier	Moisture Dissipation Multiplier
1	0.3	0.51	1	1	1
2	0.3	2.39	1	1	1
3	1.51	0.51	1	1	1
4	1.51	2.39	1	1	1
5	2.71	0.51	1	1	1
6	2.71	2.39	0	0	0
7	3.91	0.51	1	1	1
8	3.91	2.39	0	0	0
9	5.12	0.51	1	1	1
10	5.12	2.39	0	0	0

Note the zero multipliers are used to delete 3 occupants



Temperature and humidity vs. time

Example 5: 10-person RA, derated to 7-person occupancy, hanger-type CO₂ scrubber, 66.2°F ambient temperature
Reduced occupancy from one end of RA space



Temperature and condensation distribution maps

Example 6: 23-person RA, hanger-type CO₂ scrubber, 57.2 °F ambient temperature

Refuge Alternative

File Graph Reset Select Template

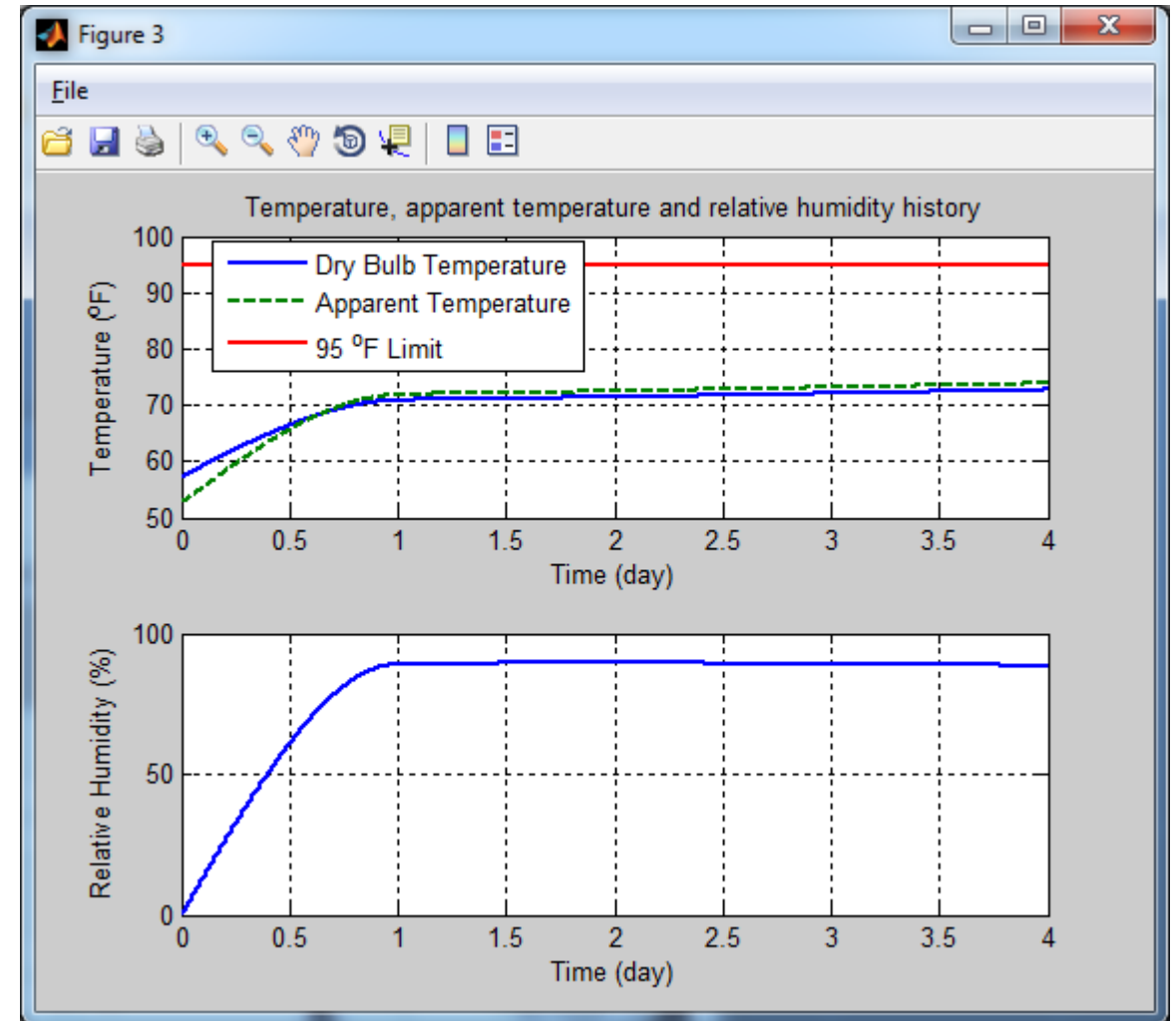
Room HSE Data General HSE Data Individual Scrubber Inside Conditions Outside Conditions RA Insulation Miscellaneous

Refuge Alternative User Input Template Auto Position

Individual Human/Scrubber/Equipment Data

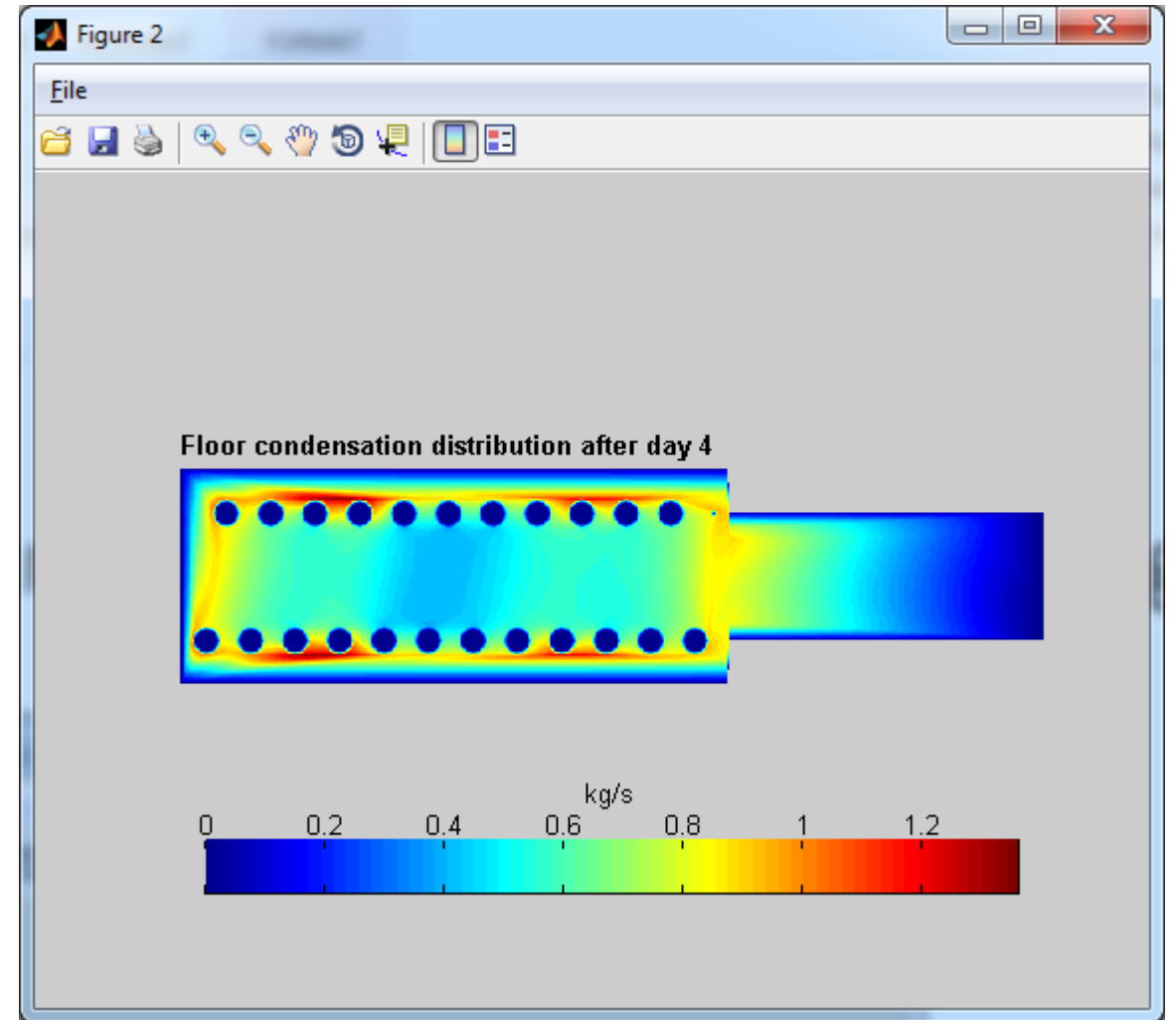
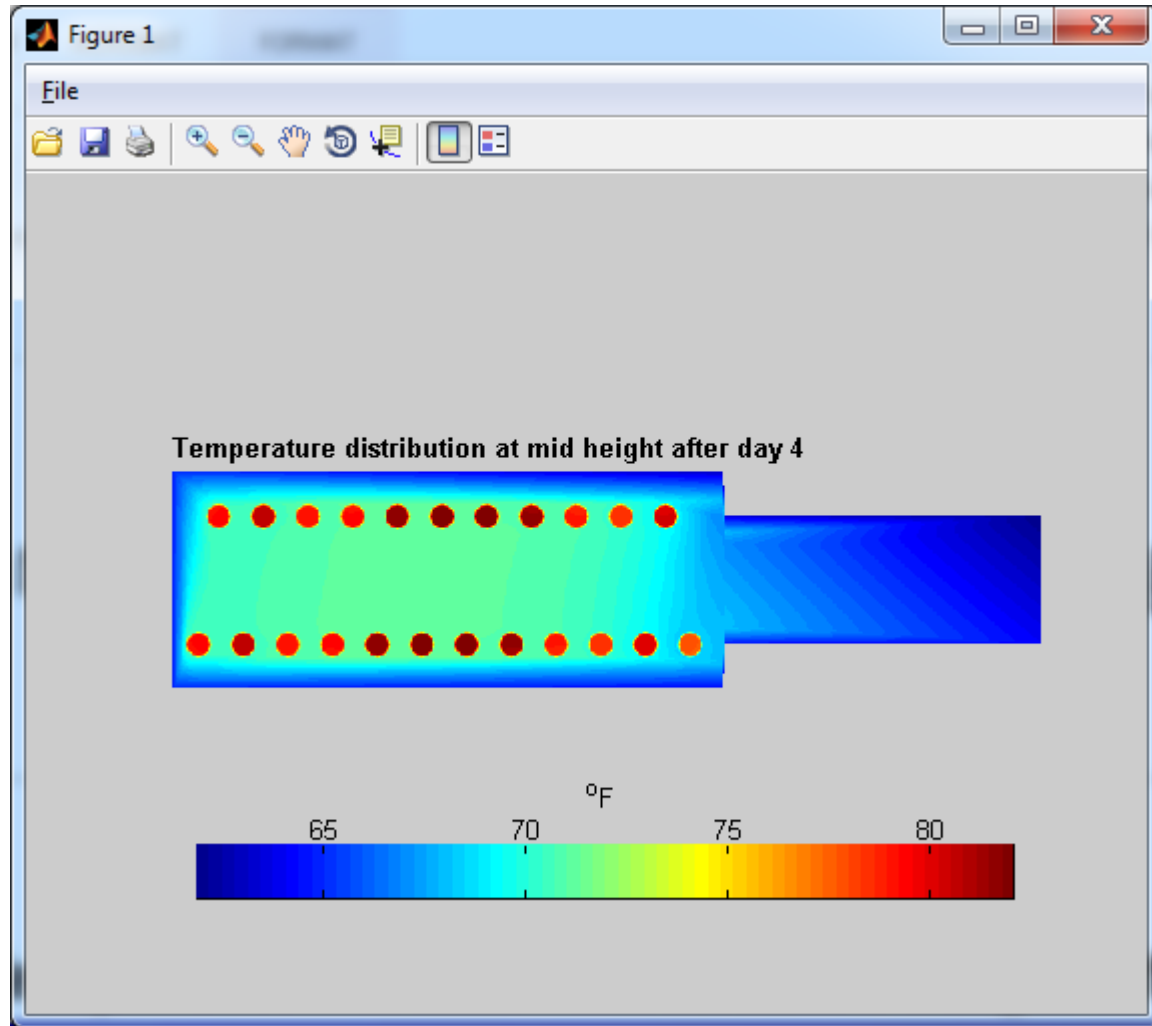
Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
1	0.4318	0.7366	1	1
2	0.7747	2.921	1	1
3	1.1938	0.7366	1	1
4	1.5367	2.921	1	1
5	1.9558	0.7366	1	1
6	2.2987	2.921	1	1
7	2.7178	0.7366	1	1
8	3.0607	2.921	1	1
9	3.4798	0.7366	1	1
10	3.8227	2.921	1	1
11	4.2418	0.7366	1	1
12	4.5847	2.921	1	1
13	5.0038	0.7366	1	1
14	5.3467	2.921	1	1
15	5.7658	0.7366	1	1
16	6.1087	2.921	1	1
17	6.5278	0.7366	1	1
18	6.8707	2.921	1	1
19	7.2898	0.7366	1	1
20	7.6327	2.921	1	1
21	8.0518	0.7366	1	1
22	8.3947	2.921	1	1
23	8.8138	0.7366	1	1
24	9.144	2.921	0	0

RUN Open Location Save Location OK Cancel



Temperature and humidity vs. time

Example 6: 23-person RA, hanger-type CO₂ scrubber, 57.2 °F ambient temperature



Temperature and condensation distribution maps

Conclusions and Recommendations

- UNR's universal RA model shown in the examples has matched the 10-person RA measurement results within a few percent from three different NIOSH experiments
- Five more sets of NIOSH's experimental results from different RA types are available for testing the universal thermal model
- The universal thermal model is integrated into Ventsim Visual mine ventilation and climate software which has customer support
- The model is easy to configure in a graphical environment and provides results for temperature, humidity, condensation, and air movement within the RA space; it gives results in a few minutes

Thank You

Question?