

UNR's Universal Thermal Model for RA Thermal Rating Verification

Presenter

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Contributed by

Davood Bahrami, UNR (MULTIFLUX thermal model)

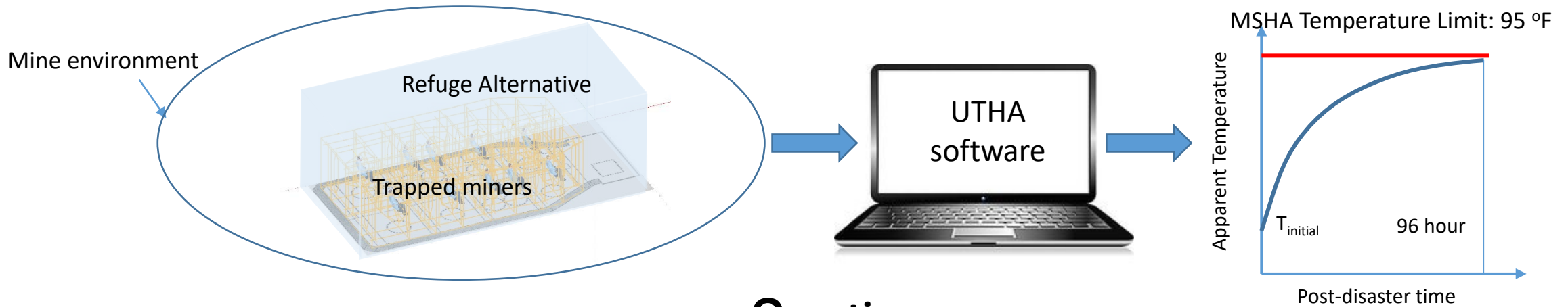
Craig Stewart and Craig Christensen, Chasm (Ventsim GUI integration)

Dave Yantek, NIOSH (GUI review)

NIOSH Partnership Meeting, October 19, 2016

BAA Project: Development of Universal Deployment Technology for Refuge Alternative

Project's goal: to develop an easy-to-use software tool for mines to check compliance of their RA at the mine site



Question

Will a given RA be compliant with $T_a < 95$ °F for a mine with a given in situ condition at the RA location?

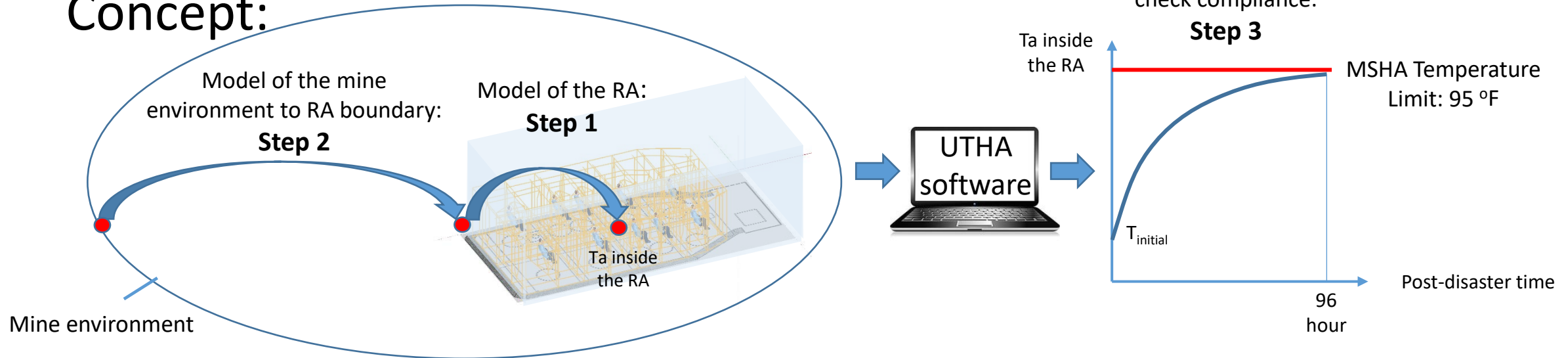
Answer

Use an approved deployment technology for answering the compliance question (Is the RA Acceptable as-is at full capacity? What can a mine do to pass the RA?)

- Step 1.** Set-up the **Universal Thermal-Humidity-Air model (UTHA)** for the specific RA from easy-to-use Graphical User Interface (GUI); use mitigation techniques in too hot or too cold mines in the input
- Step 2.** Enter easy-to-access data for in situ ambient conditions at the given mine for the RA; use mitigation techniques in too hot or too cold mines in the UTHA input
- Step 3.** Run the UTHA model for the mine and check for compliance; mitigate (down-rate, cool, heat, etc.) if needed

Development of Universal Deployment Technology for Refuge Alternative

Concept:



Step 1: Use the UTHA model for the given RA from its boundary walls to the inside air temperature, T_a . The universal RA model must work at any conceivable boundary condition:

- constant temperature (“infinite heat sink” at the wall)
- variable temperature with time and space on floor, ribs, and roof, affected by the heat from the RA
- cooling arrangement outside the RA

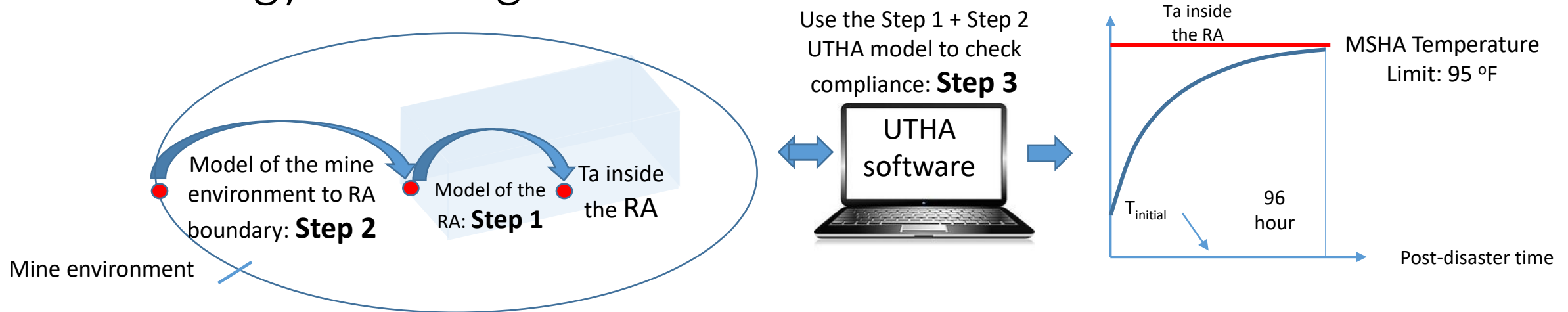
The universal RA model must also work at any conceivable internal arrangement and number of trapped miners:

- type, size and shelter capacity
- type and number of CO₂ scrubber(s): hanger or box-type
- Down-rated, variable shelter capacity for any given RA
- cooling arrangement inside or outside the RA

Step 2: Use the universal mine ambient model supported with some temperature measurements and heat conduction data for the rock strata

Step 3: Use the specified model at the mine for MSHA compliance evaluation; check capacity reduction or cooling techniques if needed for $T_a < 95^\circ\text{F}$

BAA Project: Development of Universal Deployment Technology for Refuge Alternative



Compliance checking technology

Step 1: Use the universal, qualified model of the RA from a software supplier and select the specific RA model of the mine from a Graphical User Interface (GUI) of the software:

Step 1 gives the RA model for the mine from a drop-down menu

Step 2: Take a few measurements at the RA location at the mine and obtain strata thermophysical properties for the mine. Enter the data through the GUI:

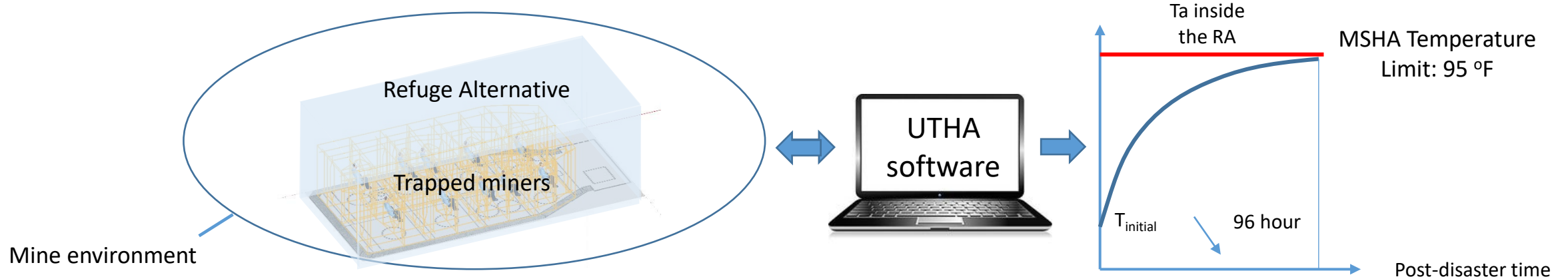
- air temperature at the RA location
- strata wall temperatures at the floor, roof and ribs
- rock heat conductivity, thermal diffusivity and density for floor, roof and ribs
- dimensions of the drift or alcove

Step 2 gives the mine environment for the RA model at the location from a drop-down menu

Step 3: Use the complete (Step 1 + Step 2) model to check compliance with MSHA regulation for maximum inside temperature in the RA in 96 hours with the modeled occupancy at the given in situ mine condition by running software from the GUI:

Step 3 plots the temperature curve to check compliance

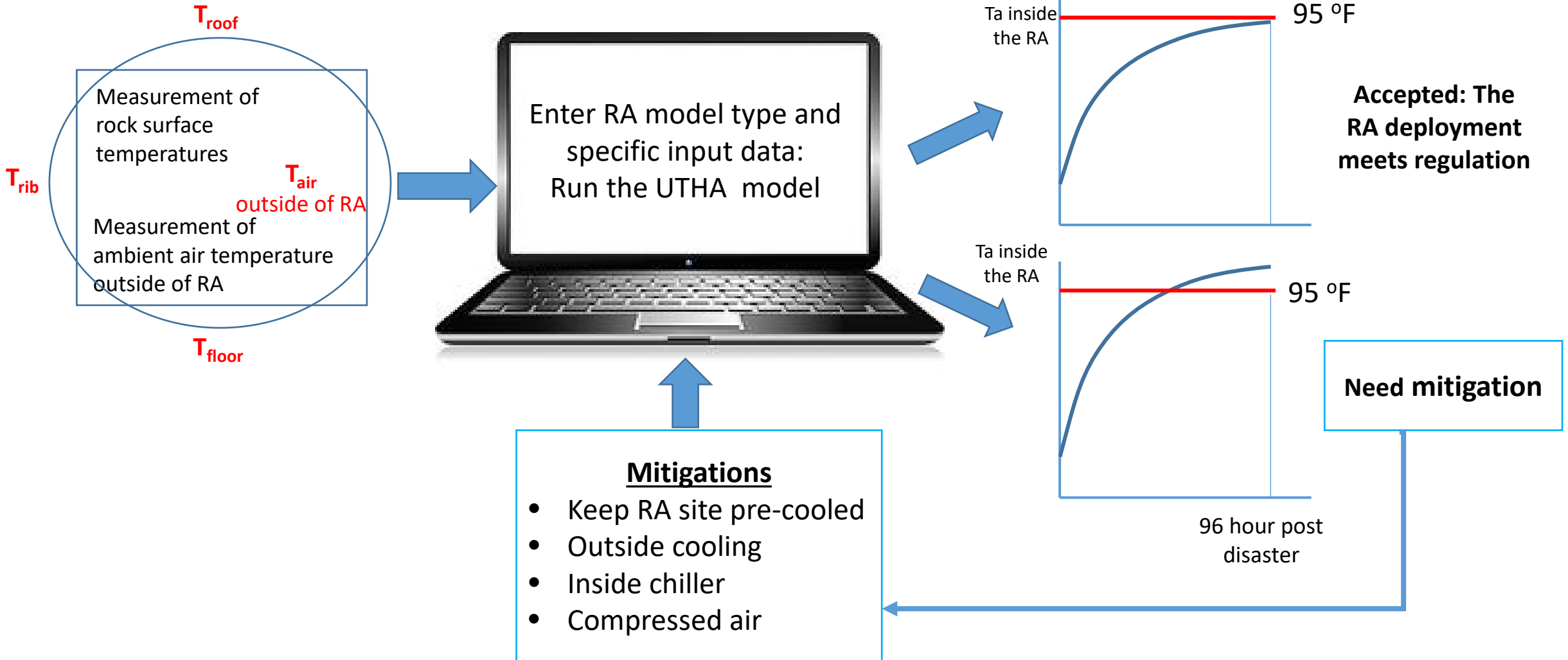
Development of Universal Deployment Technology for Refuge Alternative



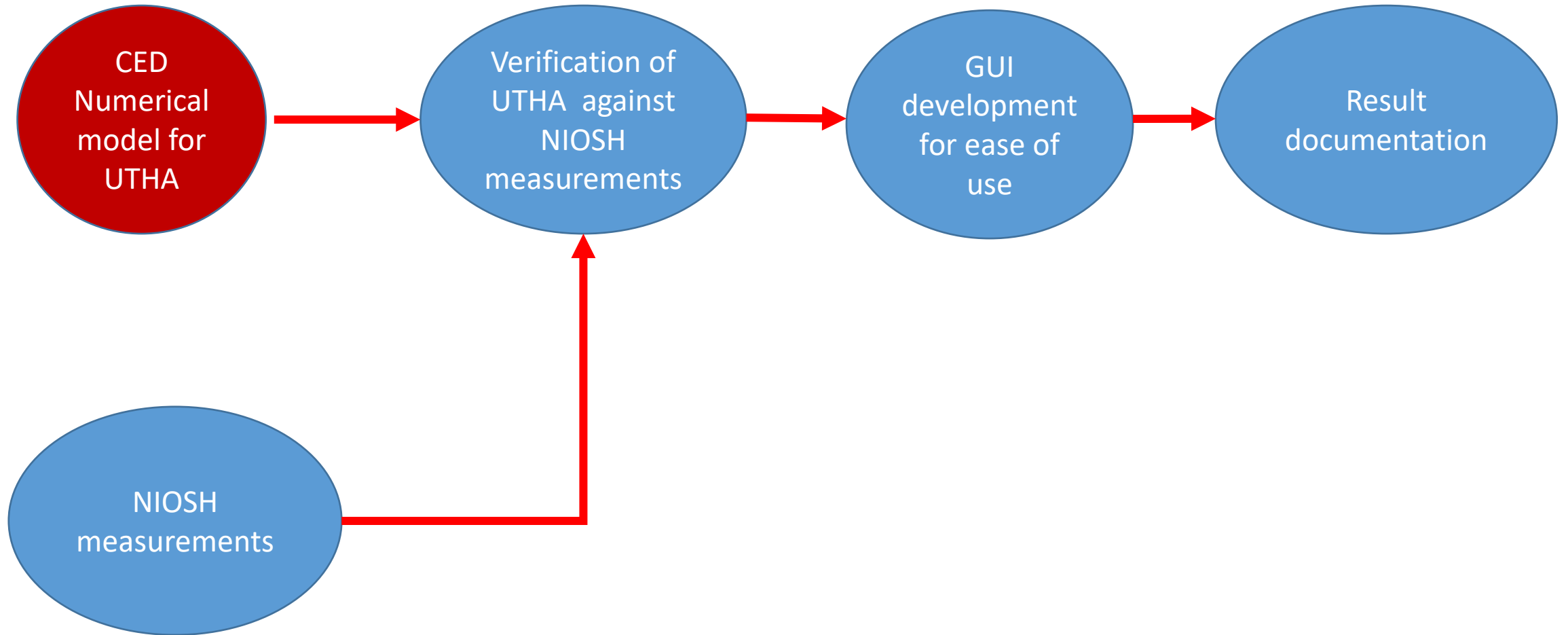
UTHA Model Development Tasks at UNR, Mackay School

- Task 1.** Develop UTHA for any RA and make UTHA work at any in situ ambient condition at any mine and in any RA test. This is done in a Computational Energy Dynamics (CED) model (similar to a CFD model)
- Task 2.** Develop and easy-to-use GUI for applying the UTHA model by operating coal mines. This is done in Ventsim Visual
- Task 3.** Test the UTHA model against experiments conducted at NIOSH by matching internal temperatures in the RAs between model simulation results and measurements using various outside conditions:
- Outside temperature
 - Strata heat flow
- Task 4.** Find a commercialization partner for qualified distribution of the UTHA model to operating mines

Use of the UTHA Model for RA Compliance Verification

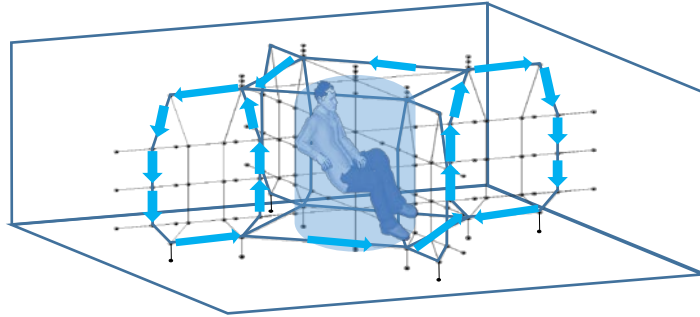


The UTHA Model Development

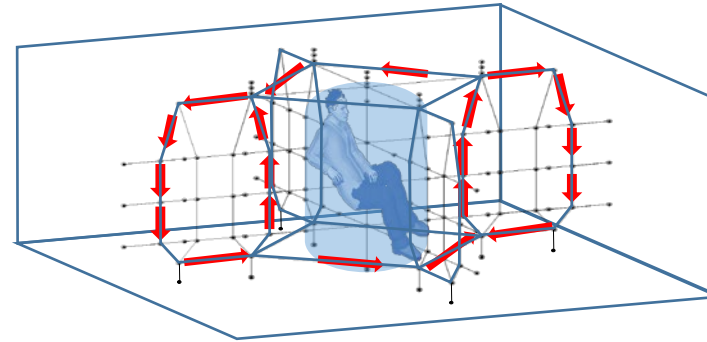


Components of the UTHA model: Human Universal Psychrometric Environment (HUPE) model-elements (1) mass and heat

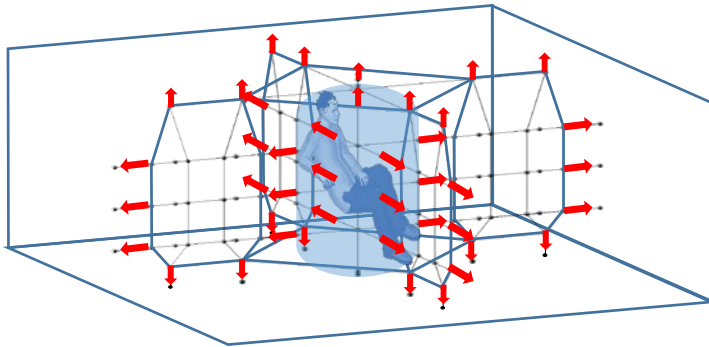
Bouyancy air flow:



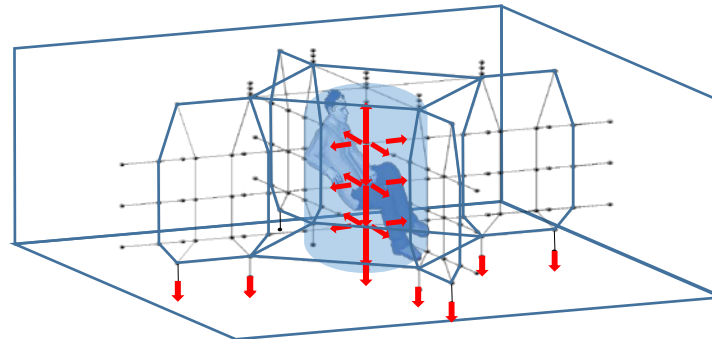
Heat advection



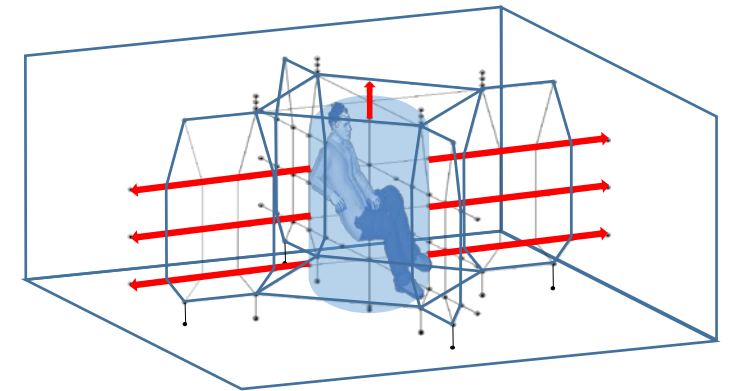
Heat convection:



Heat conduction:

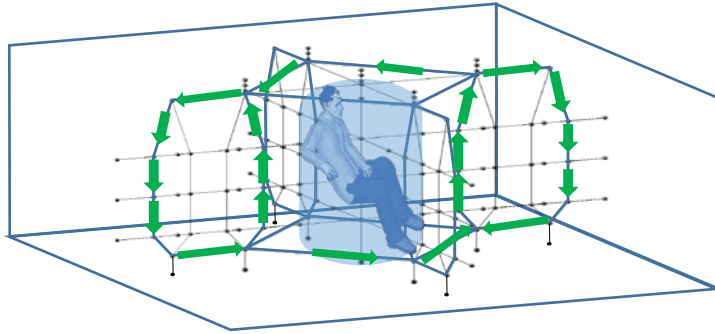


Heat radiation:

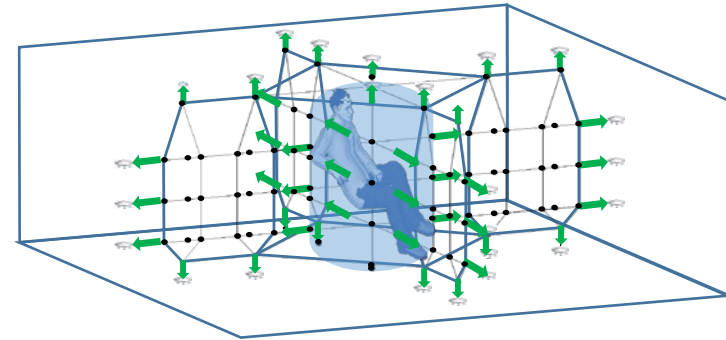


Components of UTHA: the HUPE model-elements (2) humidity and condensation

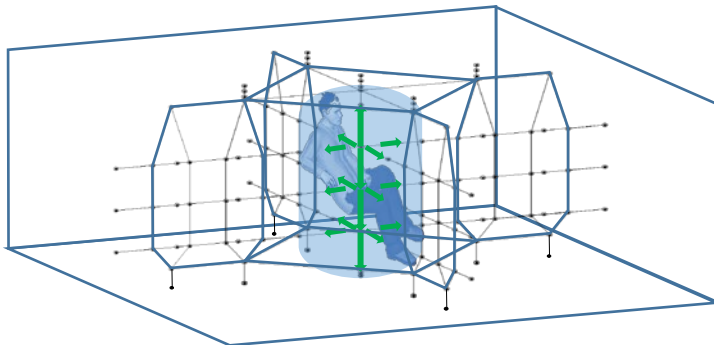
Moisture advection



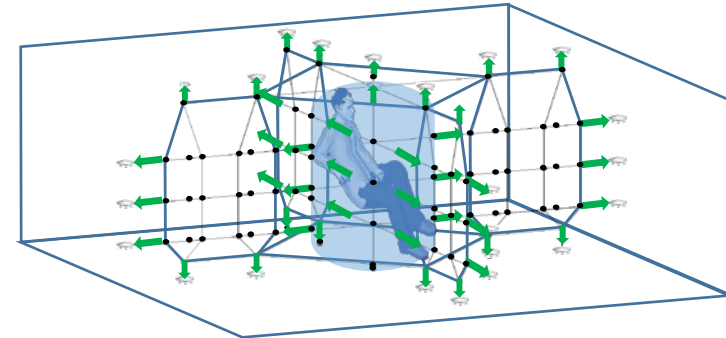
Moisture convection:



Moisture diffusion:

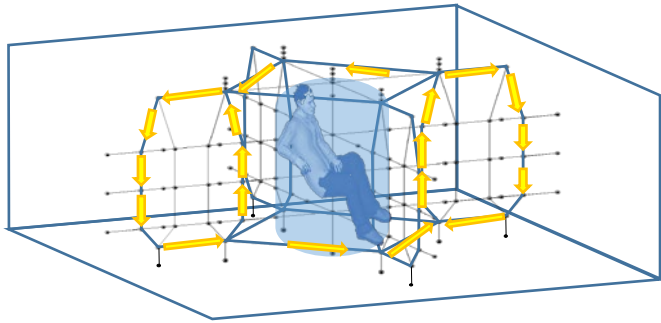


Moisture condensation:

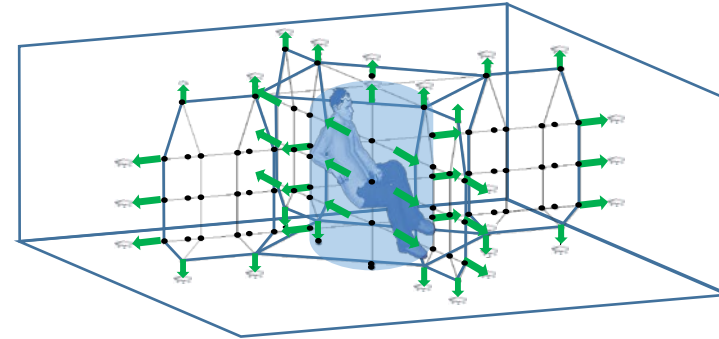


Additional components of UTHA: the HUPE model- elements upon request (3) breathing air components

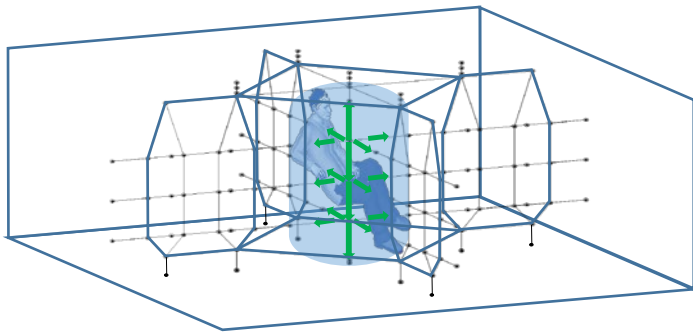
Component gas flow by air circulation:



Gas transport by convection:



Gas transport by diffusion:



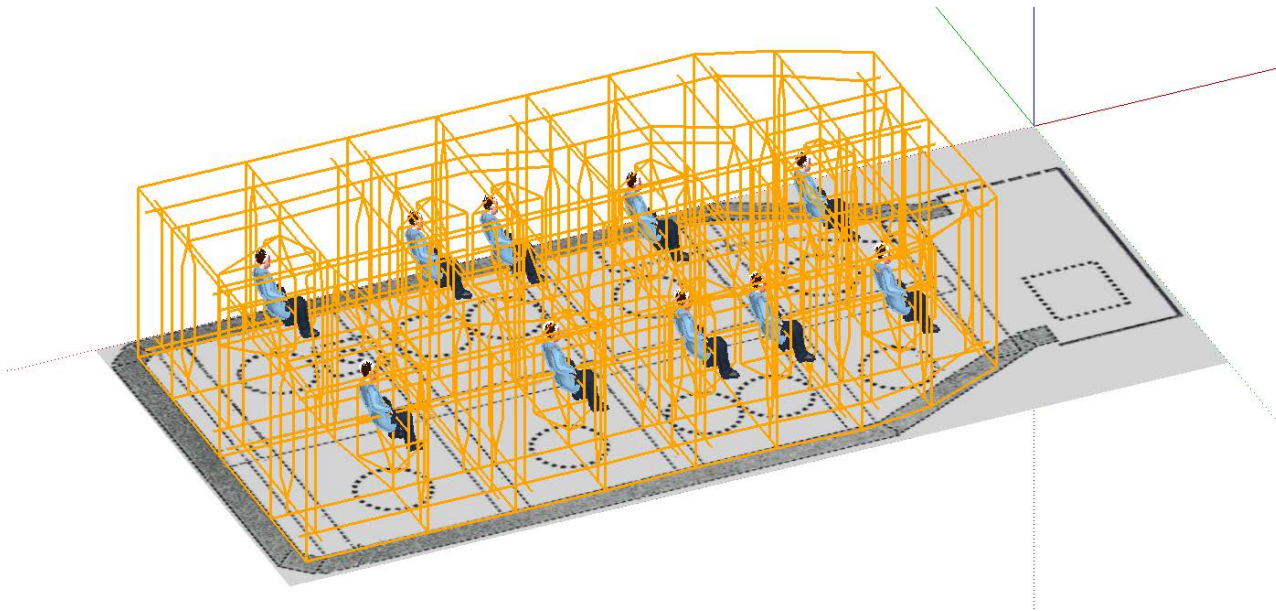
Gas components of interest:

Concentration of

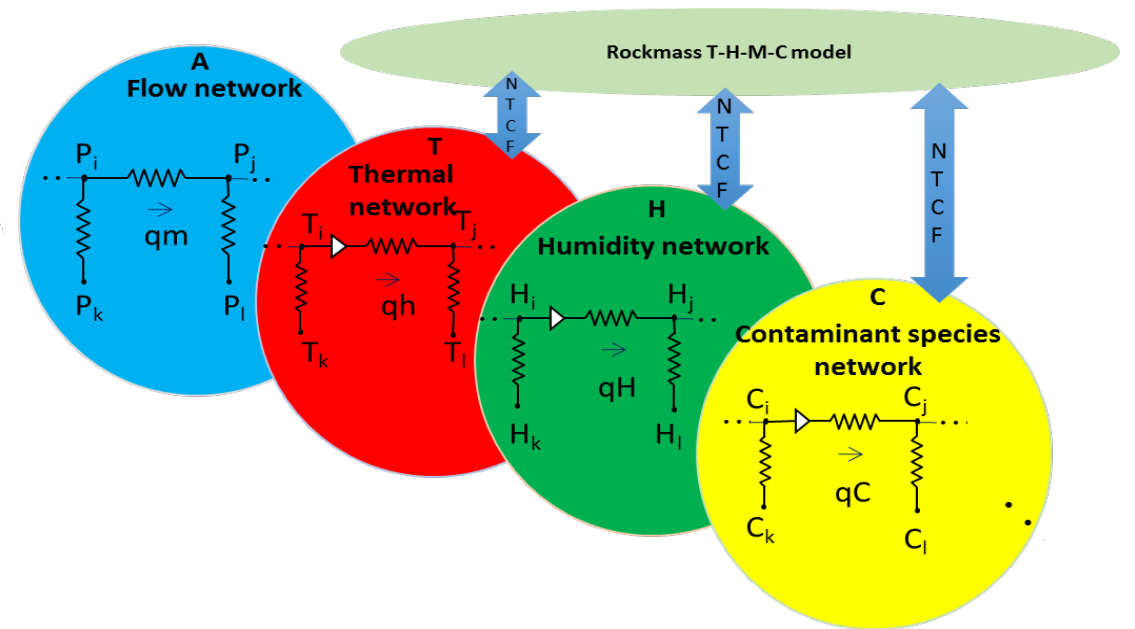
- Oxygen
- Carbon dioxide
- any contaminant to be purged

Coupled solution of the UTHA elements for an RA

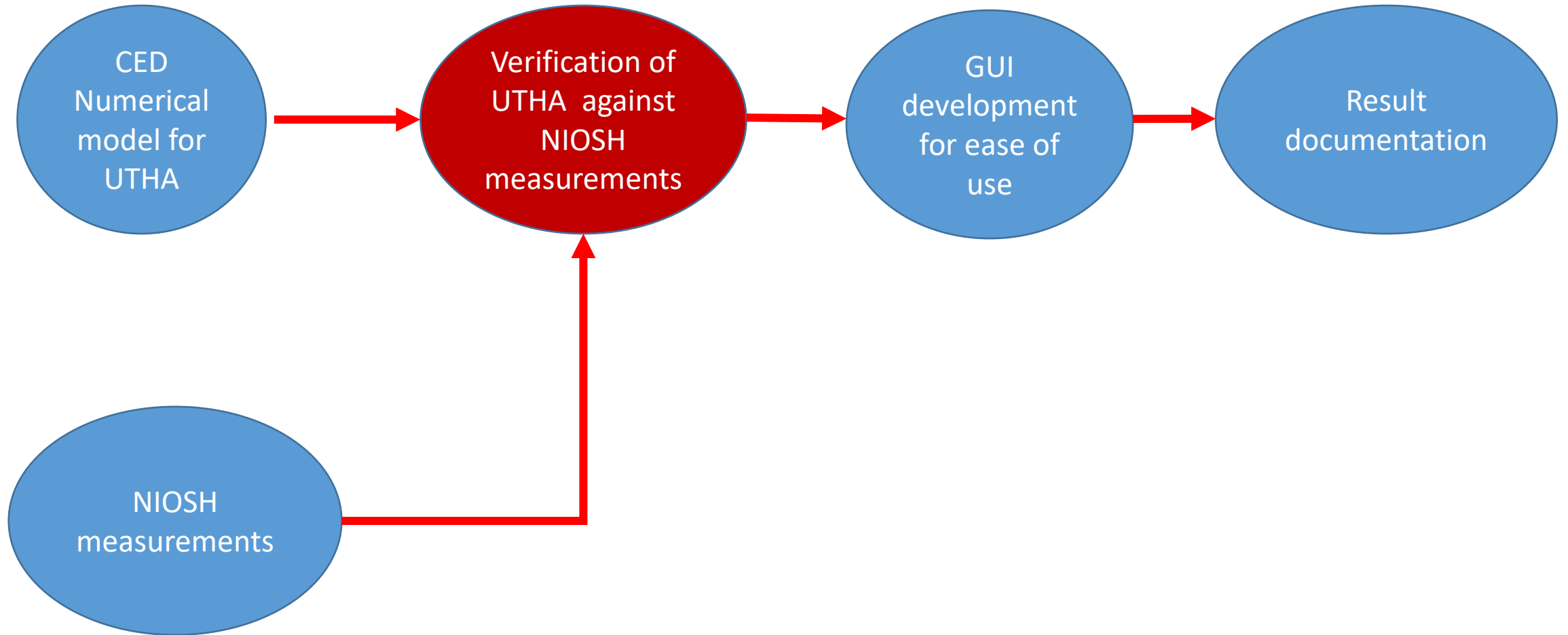
The 10-person RA example from NIOSH:



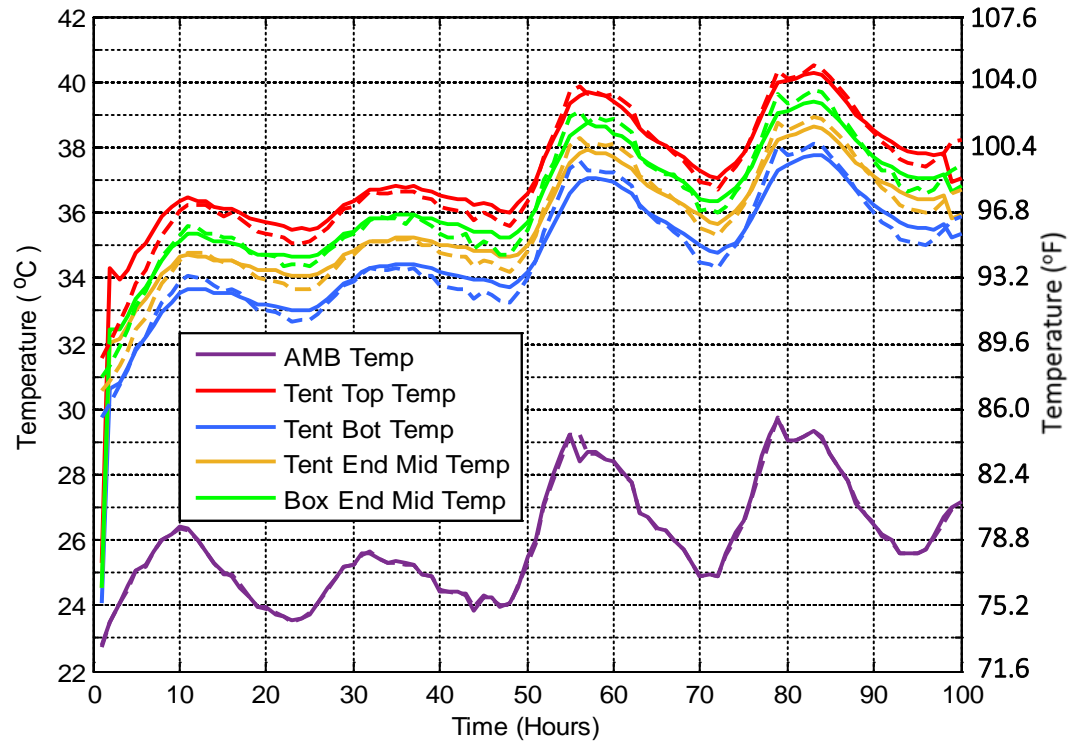
The coupled A-T-H-C and strata:



The UTHA Model Development



Model verification examples with the research model version of UTHA

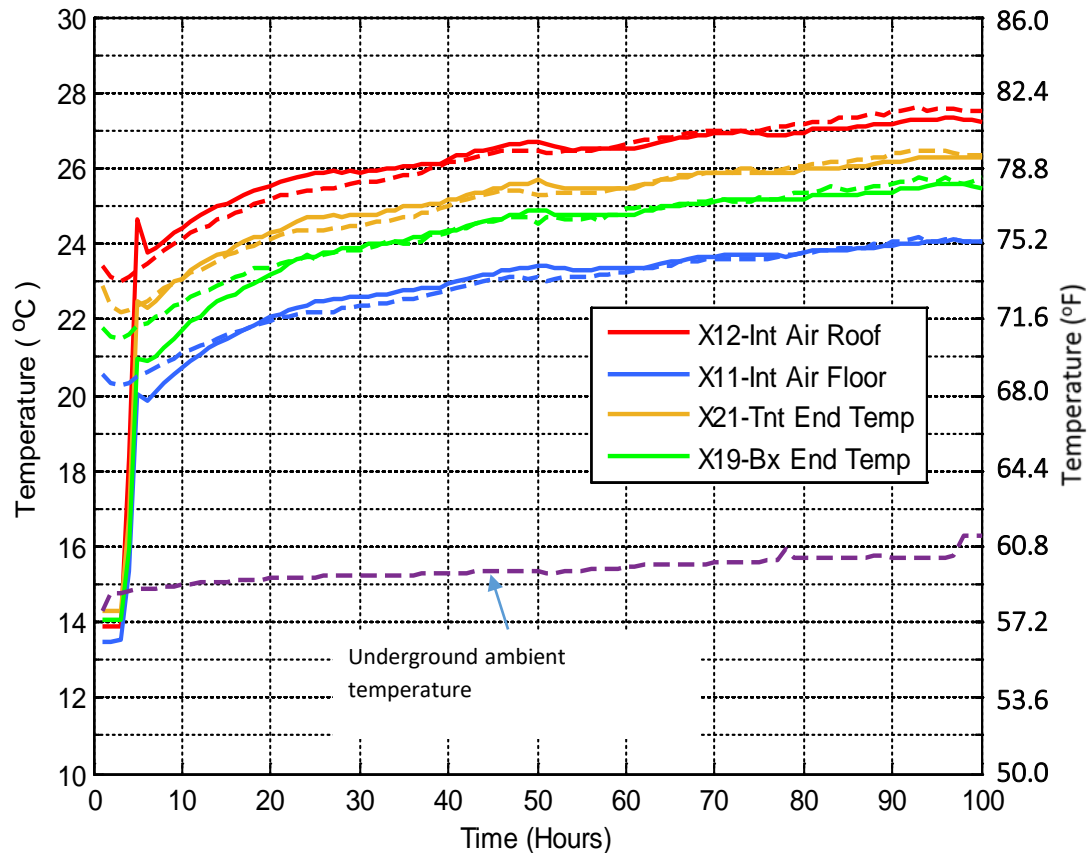


Averaged over 92-96 hours

Location	Measured		Simulated		Difference	
	[°C]	[°F]	[°C]	[°F]	[°C]	[°F]
Tent Top Temp	37.9	(100.3)	37.6	(99.7)	0.3	(0.6)
Tent Bot Temp	35.7	(96.2)	35.2	(95.3)	0.5	(0.8)
Tent End Mid Temp	36.6	(97.8)	36.2	(97.2)	0.4	(0.7)
Box End Mid Temp	37.2	(98.9)	36.8	(98.3)	0.3	(0.6)

NIOSH dry SRCM experiment. The overall RMS error of fit of those four locations is 0.4 °C (0.7 °F)

Model verification examples with the research model version of UTHA

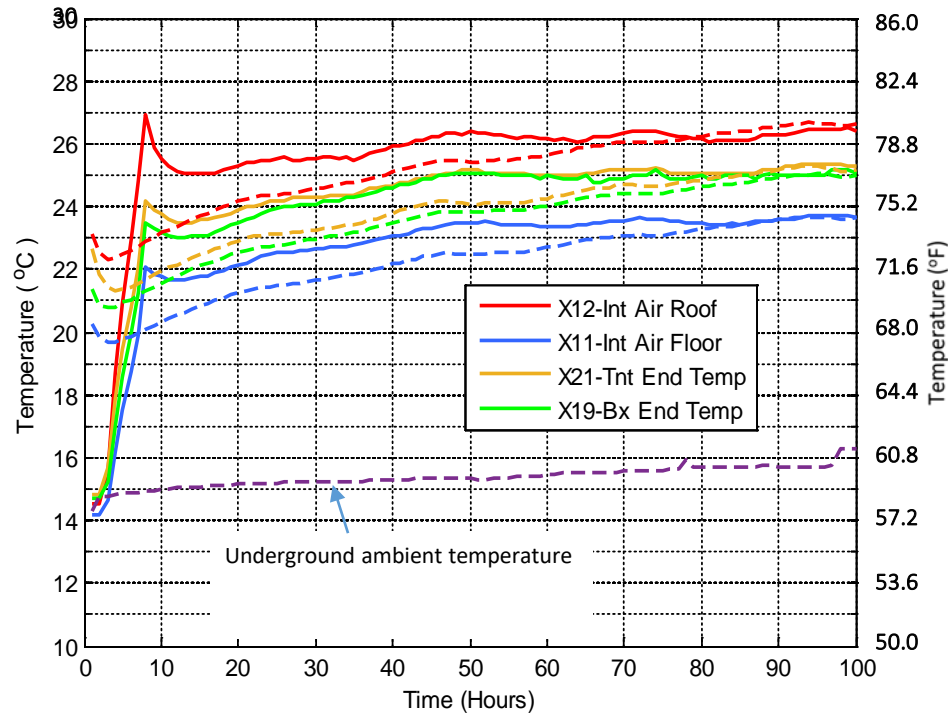


Averaged over 92-96 hours

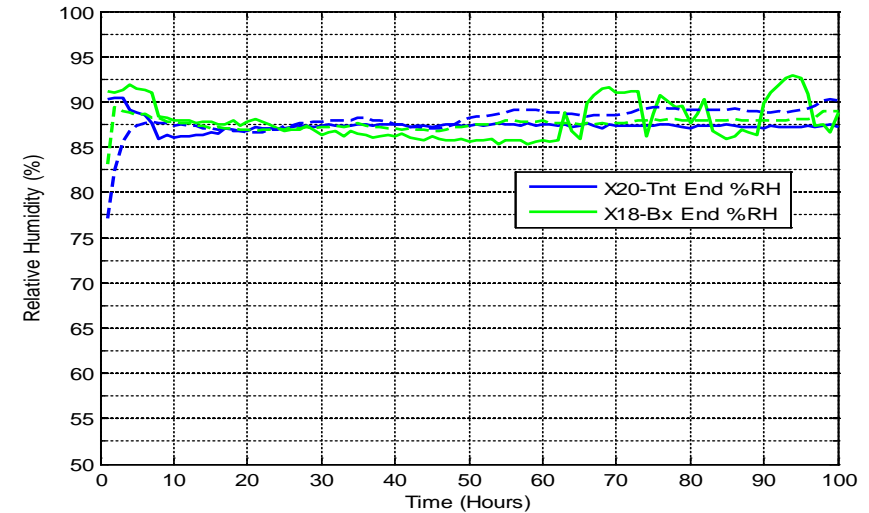
Location	Measured		Simulated		Difference	
	[°C]	[°F]	[°C]	[°F]	[°C]	[°F]
X12-Int Air Roof	27.3	(81.1)	27.6	(81.6)	-0.3	(-0.5)
X11-Int Air Floor	24.1	(75.3)	24.1	(75.4)	-0.1	(-0.1)
X21-Tnt End Temp	26.3	(79.3)	26.5	(79.6)	-0.2	(-0.3)
X19-Bx End Temp	25.5	(78)	25.7	(78.3)	-0.2	(-0.3)

NIOSH dry SRCM experiment. The overall RMS error of fit of those four locations is 0.2 °C (0.4 °F)

Model verification examples with the research model version of UTHA



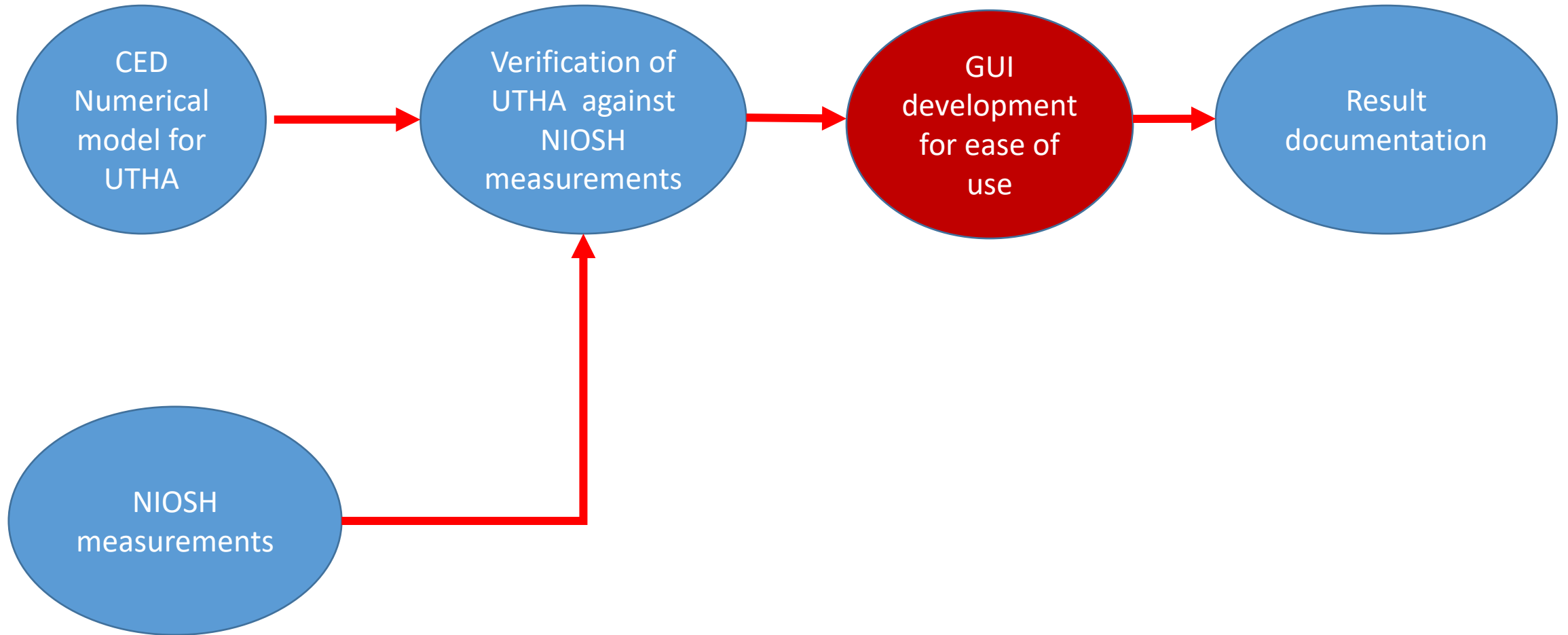
NIOSH wet SRCM experiment. The overall RMS error of fit of those four locations is 0.7 °C (1.4 °F)



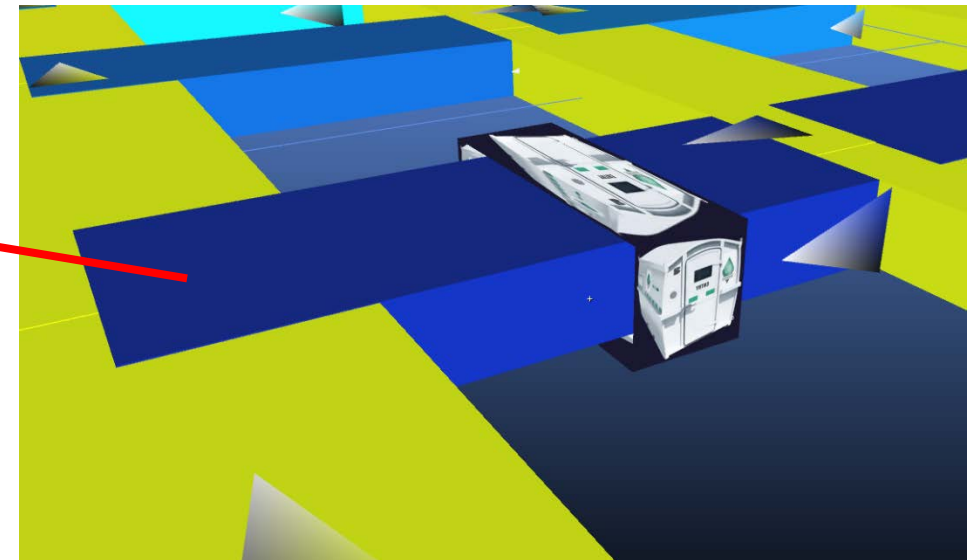
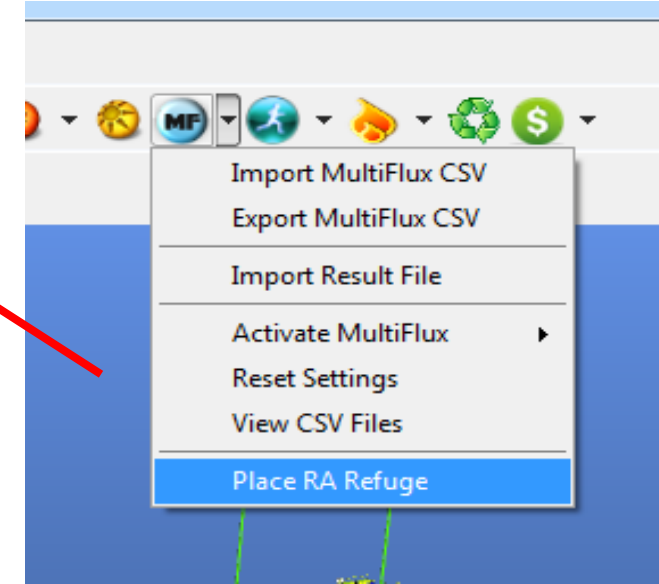
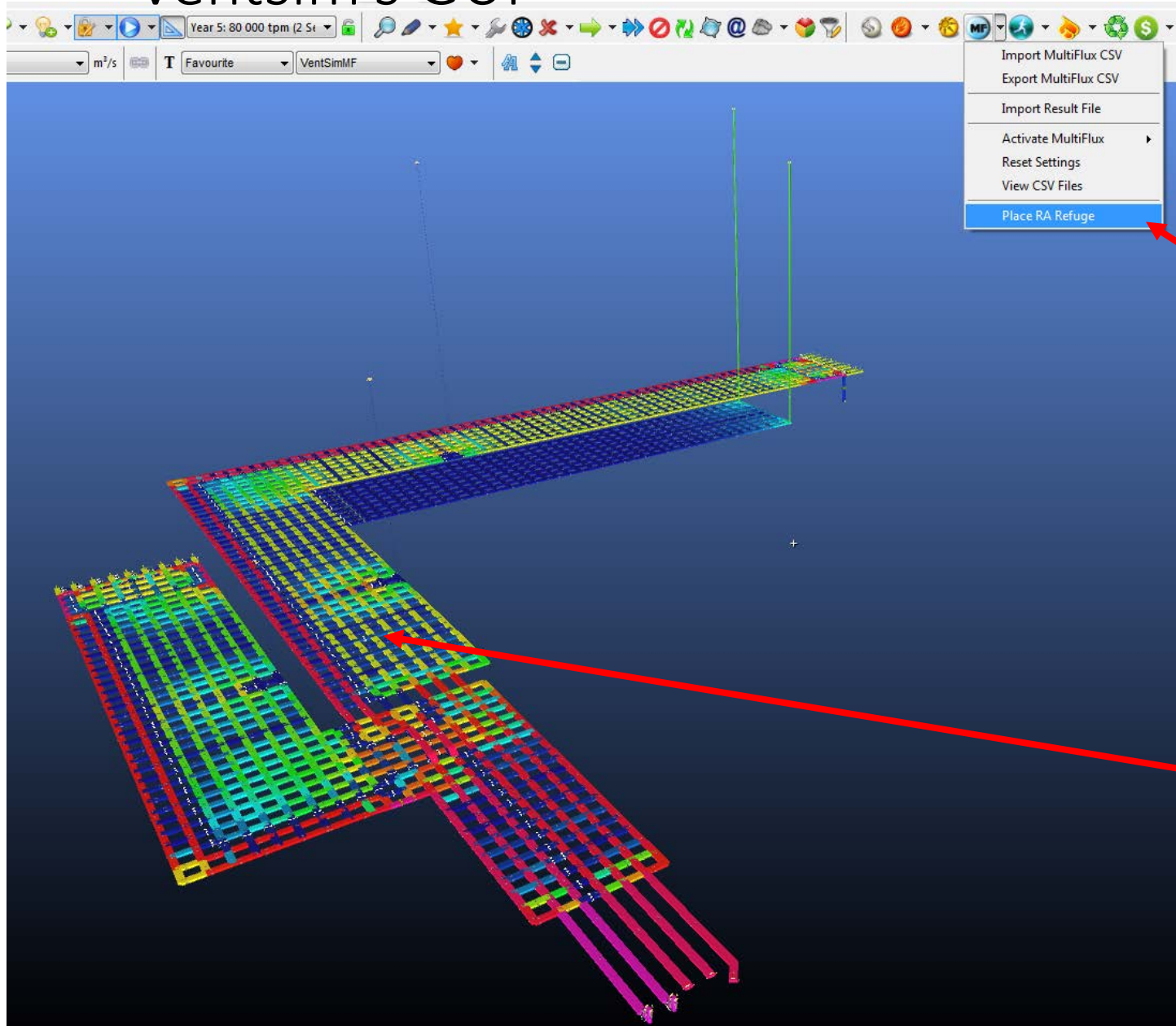
Averaged over 92-96 hours

Location	Measured		Simulated		Difference	
	[°C]	[°F]	[°C]	[°F]	[°C]	[°F]
X12-Int Air Roof	26.4	(79.5)	26.6	(79.9)	-0.2	(-0.4)
X11-Int Air Floor	25.3	(77.5)	25.4	(77.6)	-0.1	(-0.1)
X21-Tnt End Temp	25.0	(77)	25.0	(77)	0.0	(0)
X19-Bx End Temp	23.8	(74.8)	23.7	(74.7)	0.1	(0.2)

The UTHA Model Development



Model Inputs. Insertion of the location of the RA In the mine in Ventsim's GUI

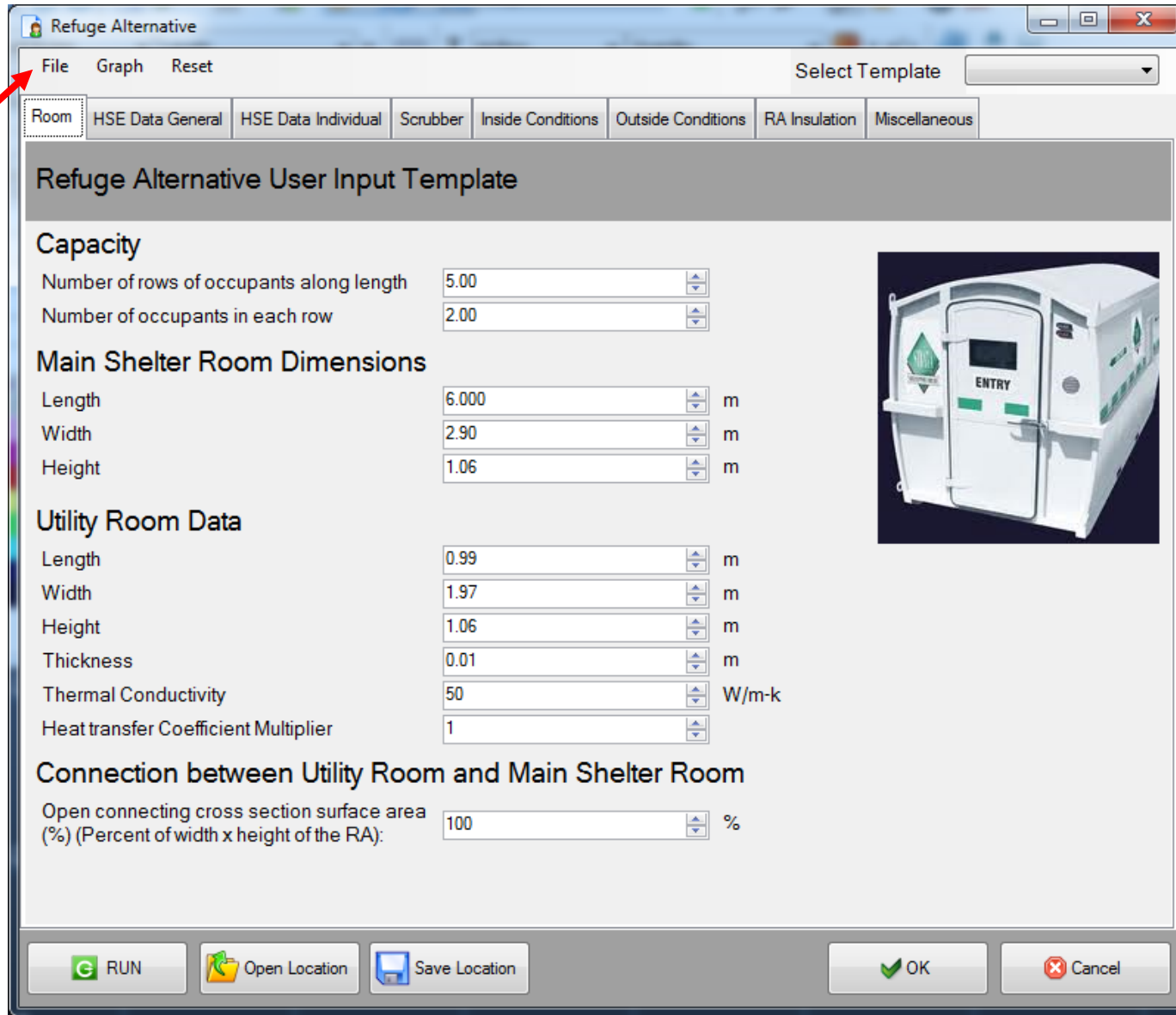
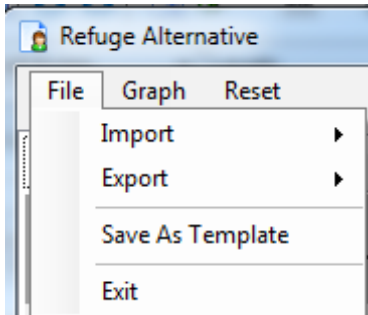


Usage from scratch with a simple mine layout: manual insertion of an RA



Data input tab for the RA in the GUI

File menu options



The screenshot shows the 'Refuge Alternative' GUI with the 'Room' tab selected. The 'Refuge Alternative User Input Template' section contains the following data input fields:

Section	Parameter	Value	Unit
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	%

The GUI also features a 'Select Template' dropdown menu, a 'Room' tab, and other tabs like 'HSE Data General', 'HSE Data Individual', 'Scrubber', 'Inside Conditions', 'Outside Conditions', 'RA Insulation', and 'Miscellaneous'. A small image of a white refuge alternative unit with a green 'ENTRY' sign is visible on the right side of the input fields.

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. Below the menu is a tabbed interface with the following tabs: Room, HSE Data General (selected), 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 a section for "General Human/Scrubber/Equipment Data". This section lists ten parameters, each with a numerical input field and a unit. At the bottom of the window are buttons for "RUN", "Open Location", "Save Location", "OK", and "Cancel".

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

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

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 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

Y---->

Disable Occupant

Enable
Disable

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. Below the menu is a tabbed interface with the following tabs: Room, HSE Data General, HSE Data Individual, Scrubber, Inside Conditions (selected), Outside Conditions, RA Insulation, and Miscellaneous. The main content area is titled "Refuge Alternative User Input Template" and is divided into two sections:

- Initial Conditions Inside the RA**
 - Air temperature: 14.0 oC
 - Air humidity: 0.0 %
 - Barometric pressure at RA floor level: 100000 Pa
- Initial Conditions Outside the RA**
 - Air temperature: 14.0 oC
 - Air relative humidity: 0.0 %
 - Air velocity: 2.0 m/s
 - Initial steady state air temperature: 14.0 oC
 - Rib steady-state surface temperature: 14.0 oC
 - Floor steady-state surface temperature: 14.0 oC
 - Roof steady-state surface temperature: 14.0 oC

At the bottom of the window, there are several buttons: "RUN" (with a green 'G' 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 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

Data for Outside Environment

Drift cross section	15.0	m ²
Drift perimeter	16.0	m
Drift Length	20.0	m
Drift age of ventilation	2.0	year
Virgin rock temperature	14.0	oC
Rib wall thermal conductivity	0.33	W/m-K
Rib wall specific heat	1380	J/kg-K
Rib wall density	1346	kg/m ³
Rib wall heat transfer coefficient multiplier	1	
Floor conductivity	2.5	W/m-K
Floor specific heat	1000	J/kg-K
Floor density	2600	kg/m ³
Floor heat transfer coefficient multiplier	1	
Roof conductivity	1.06	W/m-K
Roof specific heat	930	J/kg-K
Roof density	2600	kg/m ³
Roof heat transfer coefficient multiplier	1	W/m ² -K

RUN Open Location Save Location OK Cancel

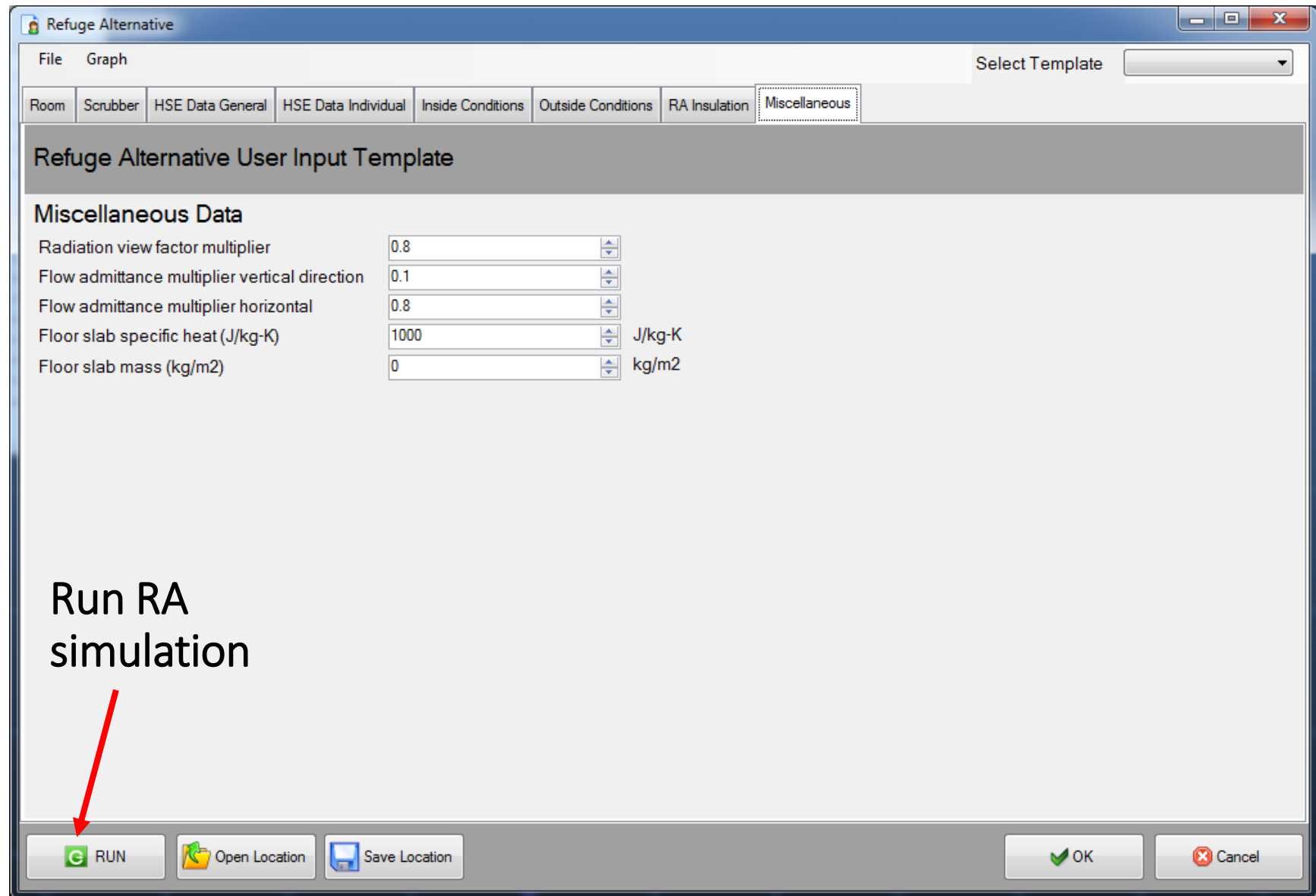
Data input tab for RA in the GUI

The screenshot shows the 'Refuge Alternative' software interface. The 'RA Insulation' tab is selected, displaying a 'Refuge Alternative User Input Template'. The template is organized into five sections, each with three input fields: thickness, thermal conductivity, and heat transfer coefficient multiplier. The values are as follows:

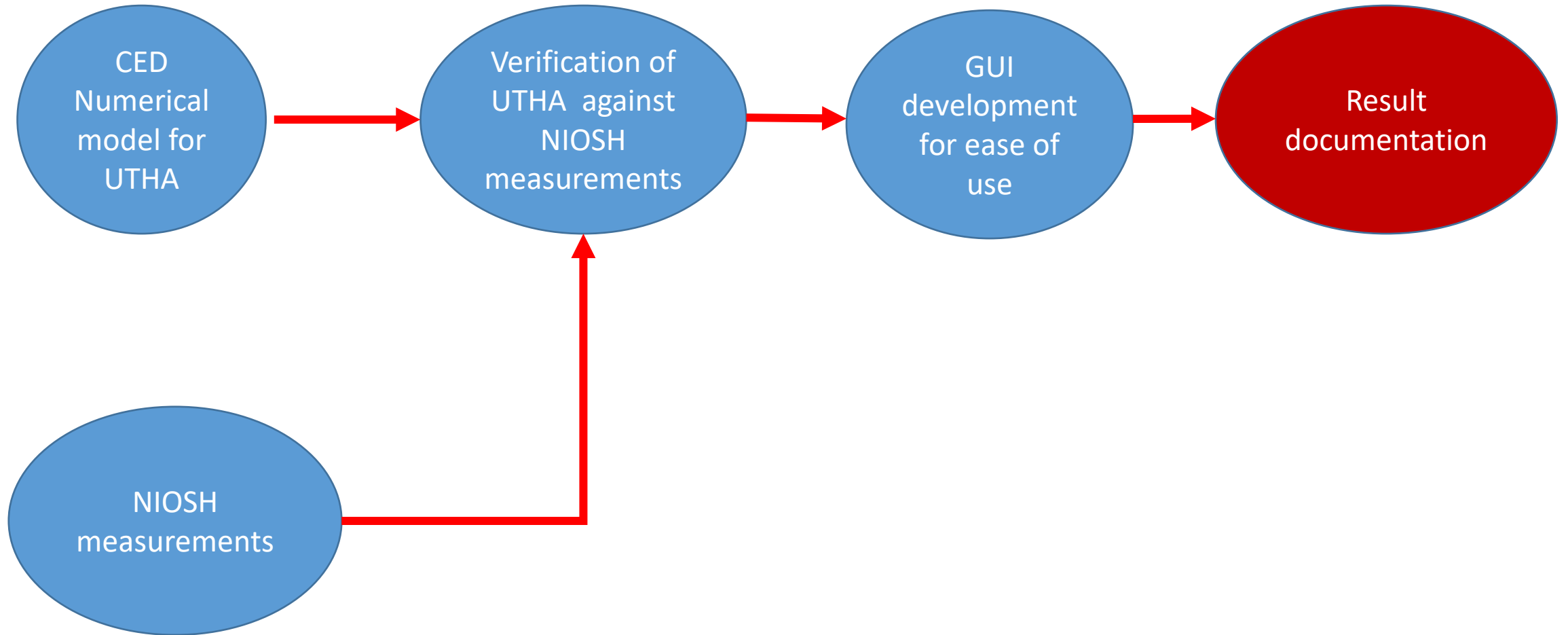
Section	Thickness (m)	Thermal Conductivity (W/m-K)	Heat Transfer Coefficient Multiplier
RA Side Wall Thermal Properties	0.002	0.2	1
RA Roof Thermal Properties	0.002	0.2	1
RA Floor Thermal Properties	0.002	0.2	1
RA Floor Thermal Properties Under Occupants	0.001	0.03	1
Thermal Personal Properties under Occupants	0.00127	0.2	1

The interface includes a menu bar (File, Graph, Reset), a 'Select Template' dropdown, and a tabbed interface with 'Room', 'HSE Data General', 'HSE Data Individual', 'Scrubber', 'Inside Conditions', 'Outside Conditions', 'RA Insulation', and 'Miscellaneous'. At the bottom, there are buttons for 'RUN', 'Open Location', 'Save Location', 'OK', and 'Cancel'.

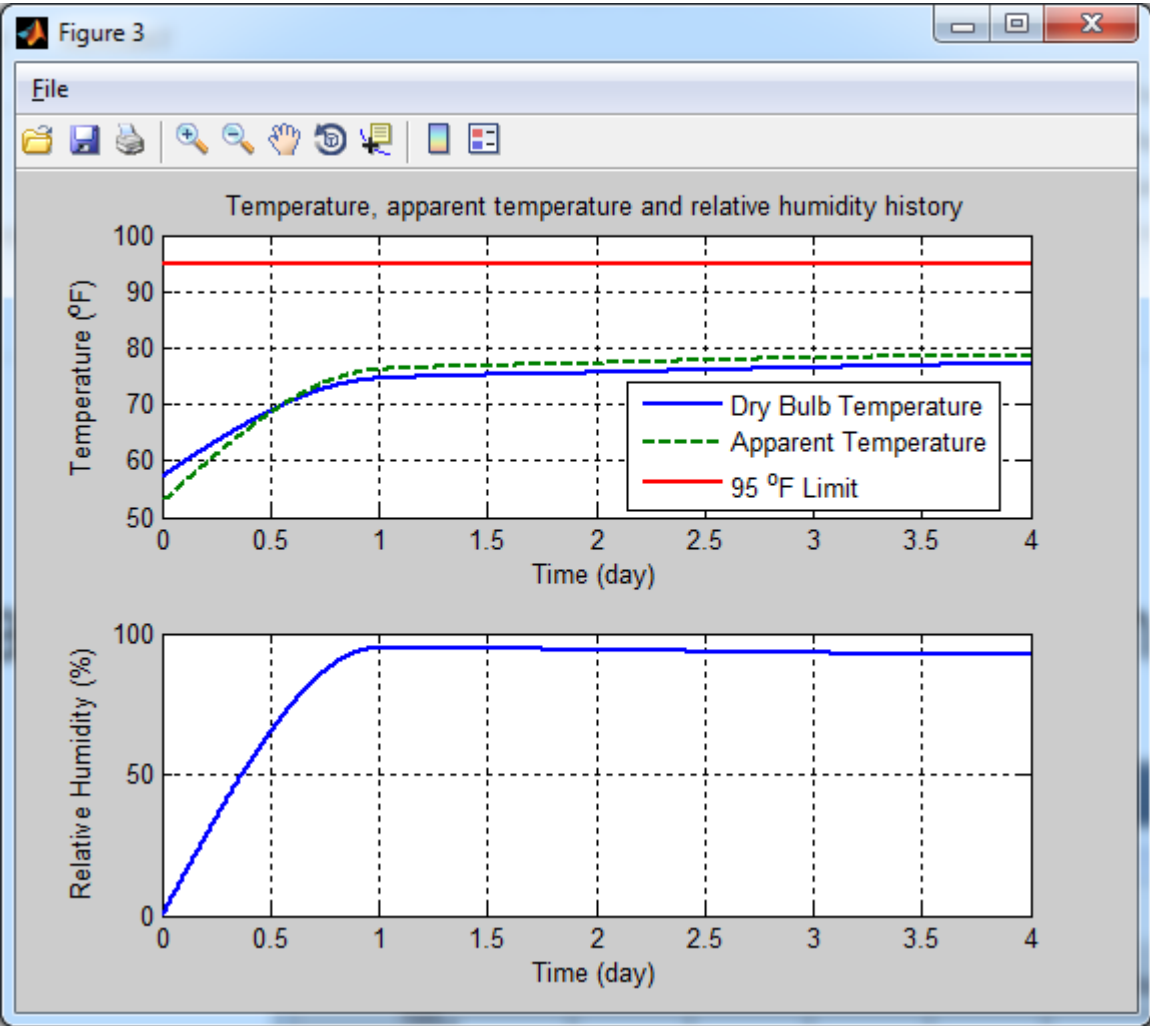
Data input tab for the RA in the GUI



The UTHA Model Development

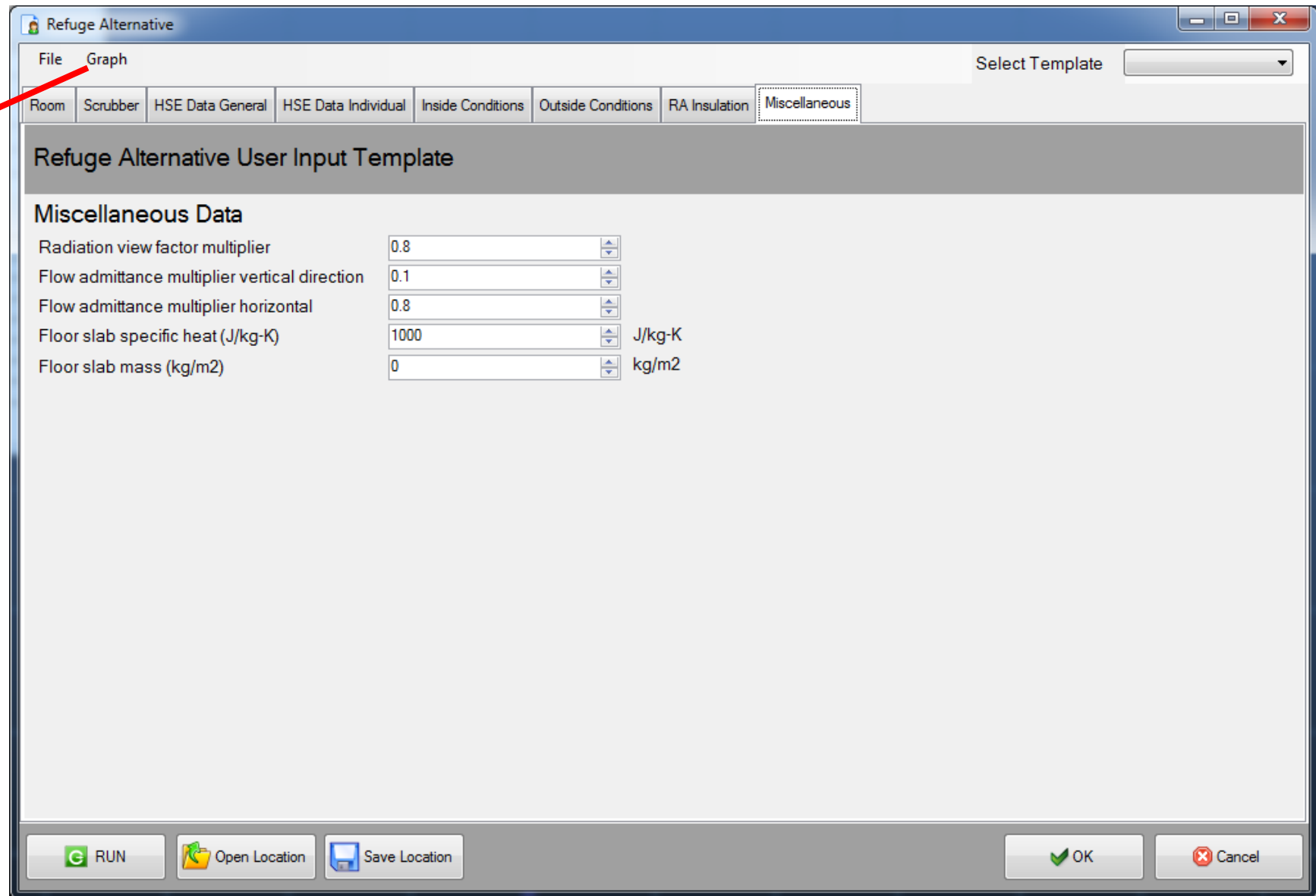
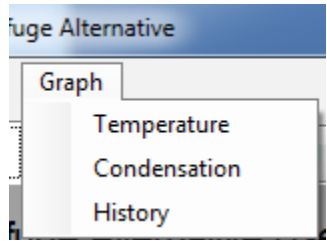


Temperature history plot upon successful completion of simulation



Results visualization control in the GUI

Graph menu options

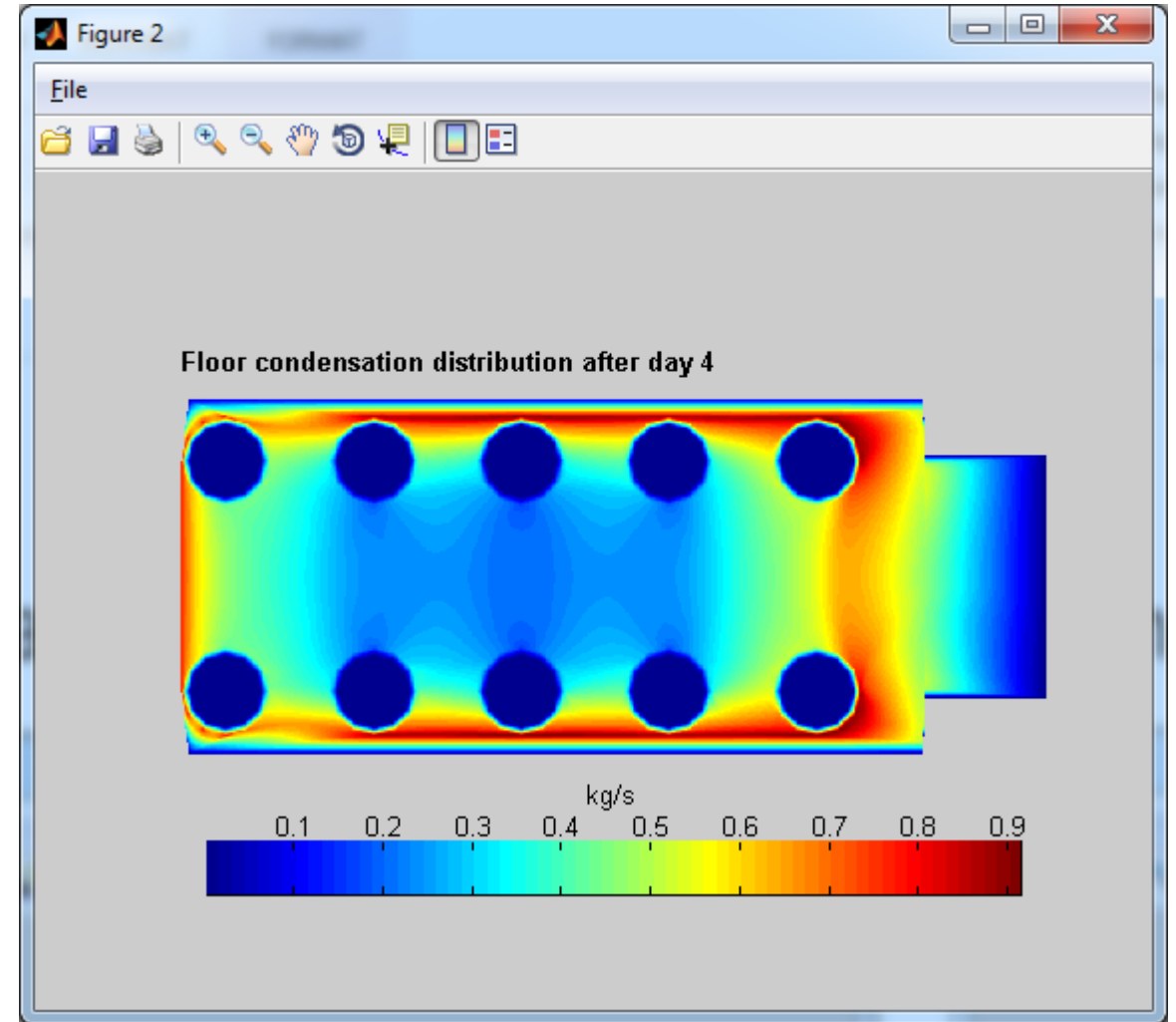
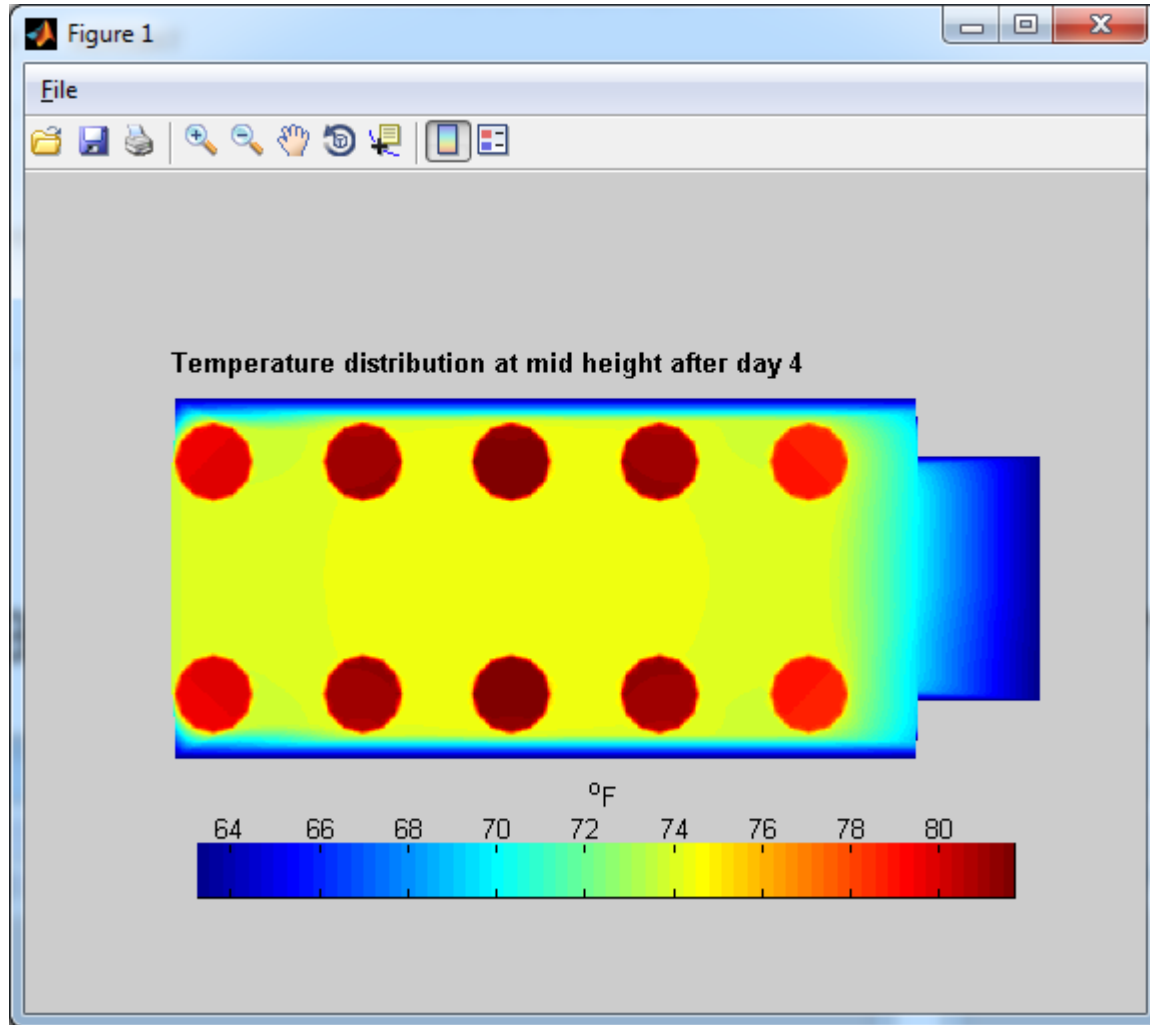


The screenshot shows the 'Refuge Alternative' application window. The 'Graph' menu is open, and the 'Miscellaneous' tab is selected. The 'Miscellaneous Data' section contains the following parameters and values:

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/m2)	0	kg/m2

The bottom of the window features a toolbar with 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 application 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 a sub-section 'Individual Human/Scrubber/Equipment Data'. This section features a table with 10 rows of data and a corresponding 2x10 grid of green circles representing occupant positions. The table columns are 'Index', 'X Position', 'Y Position', 'Surface Multiplier', and 'Heat Multiplier'. The grid has two columns and ten rows, with circles numbered 1 through 10. The bottom of the window has a toolbar with buttons for 'RUN', 'Open Location', 'Save Location', 'OK', and 'Cancel'.

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

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

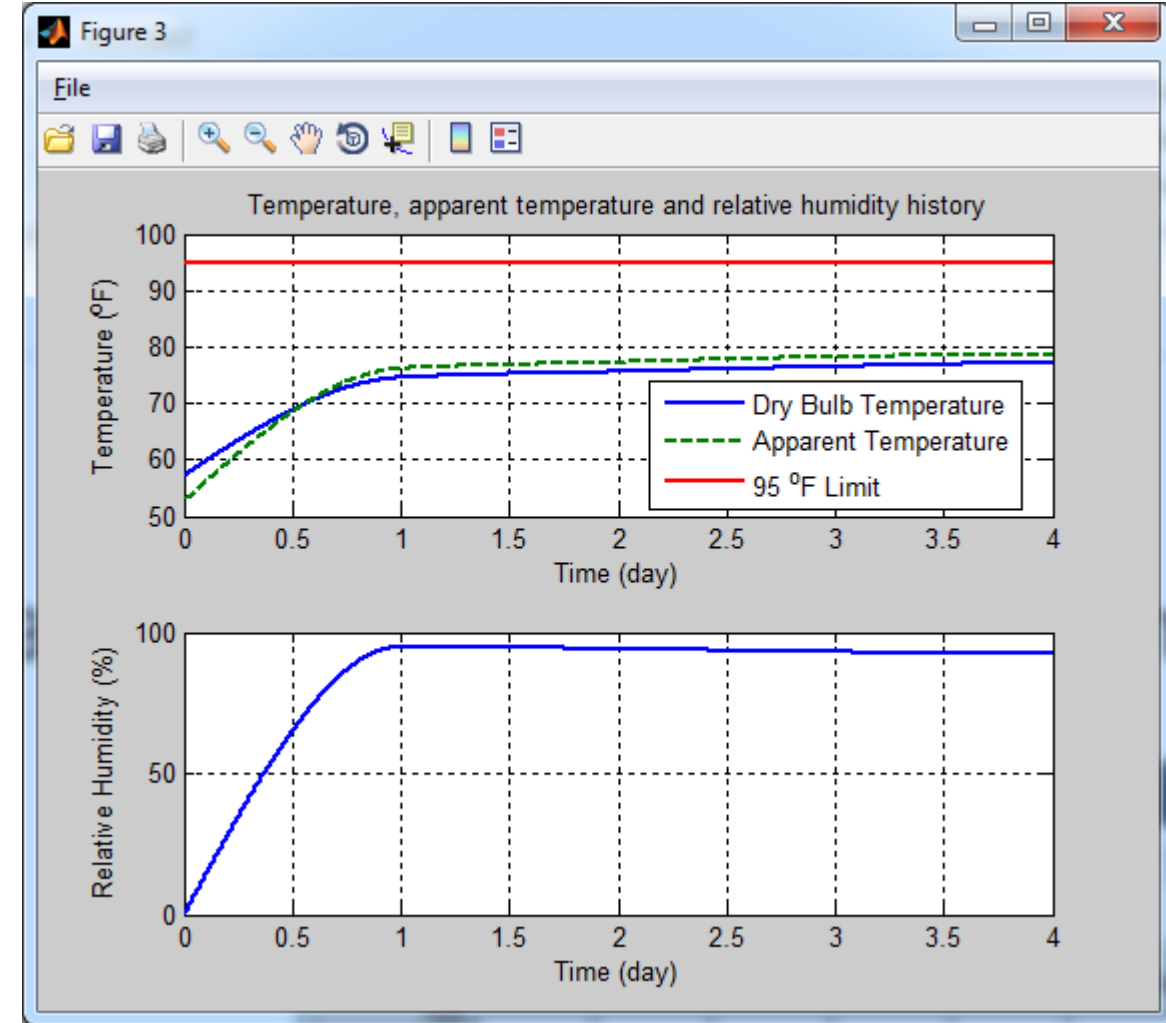
Refuge Alternative User Input Template Auto Position

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

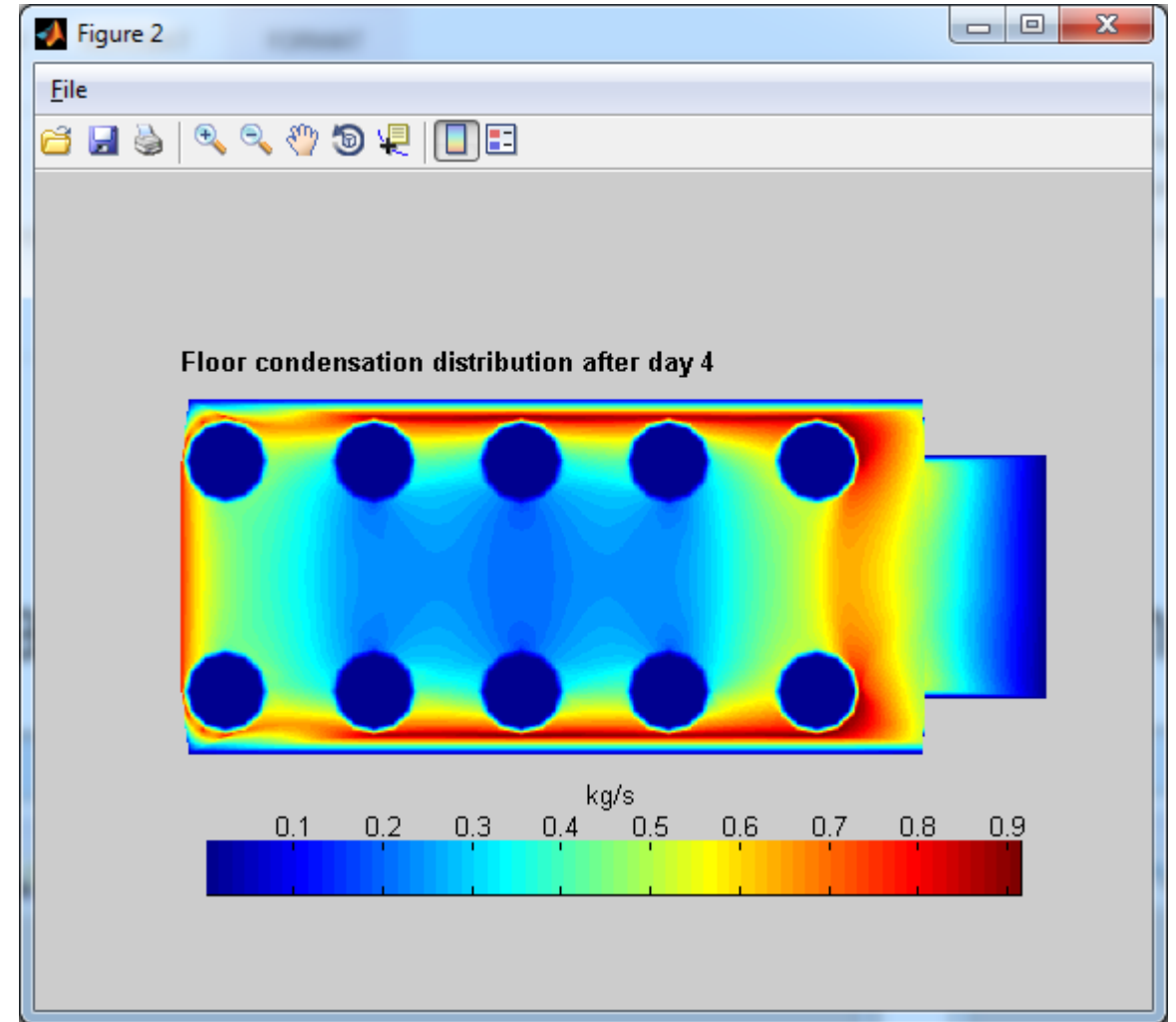
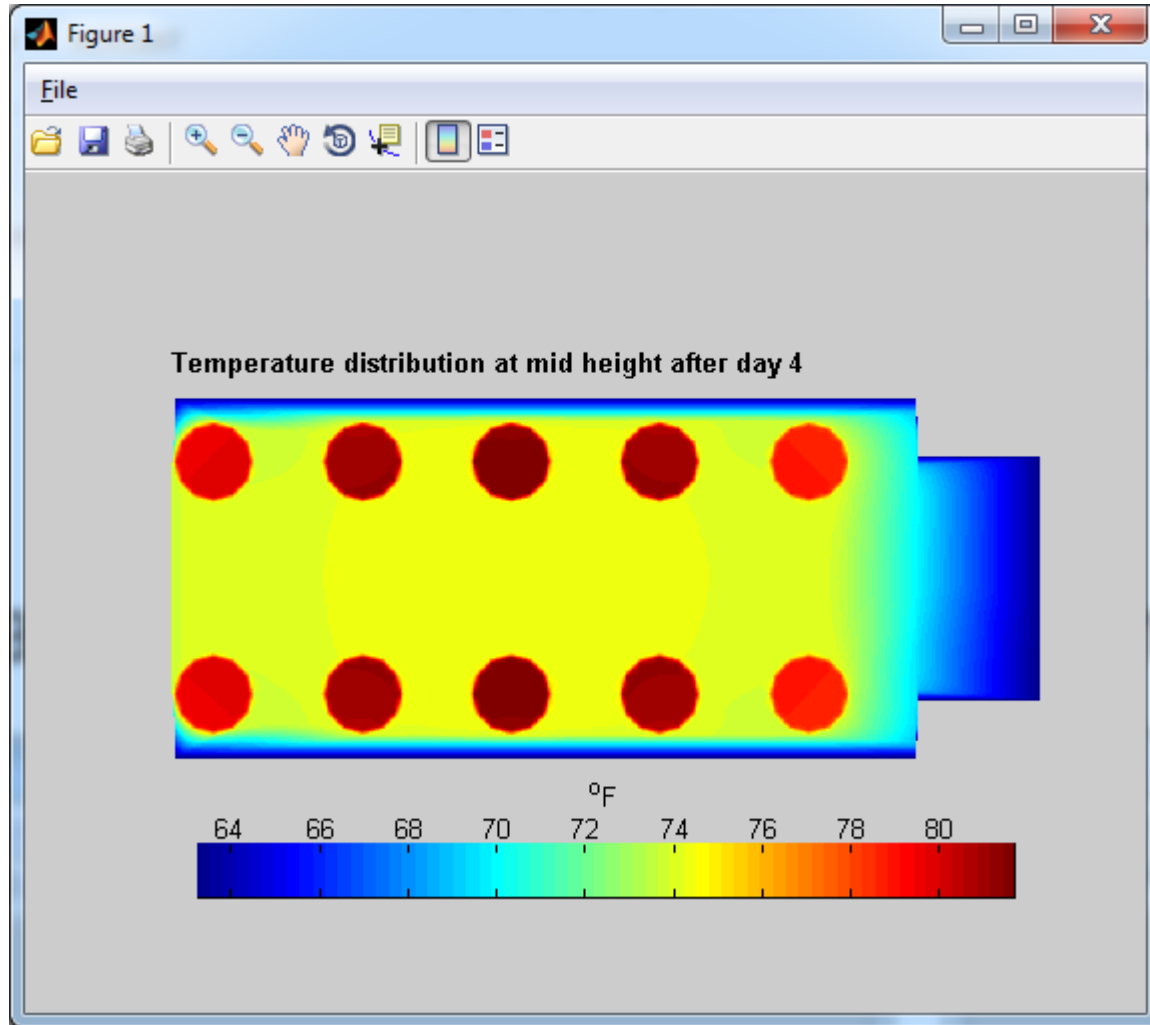
Y---->

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)



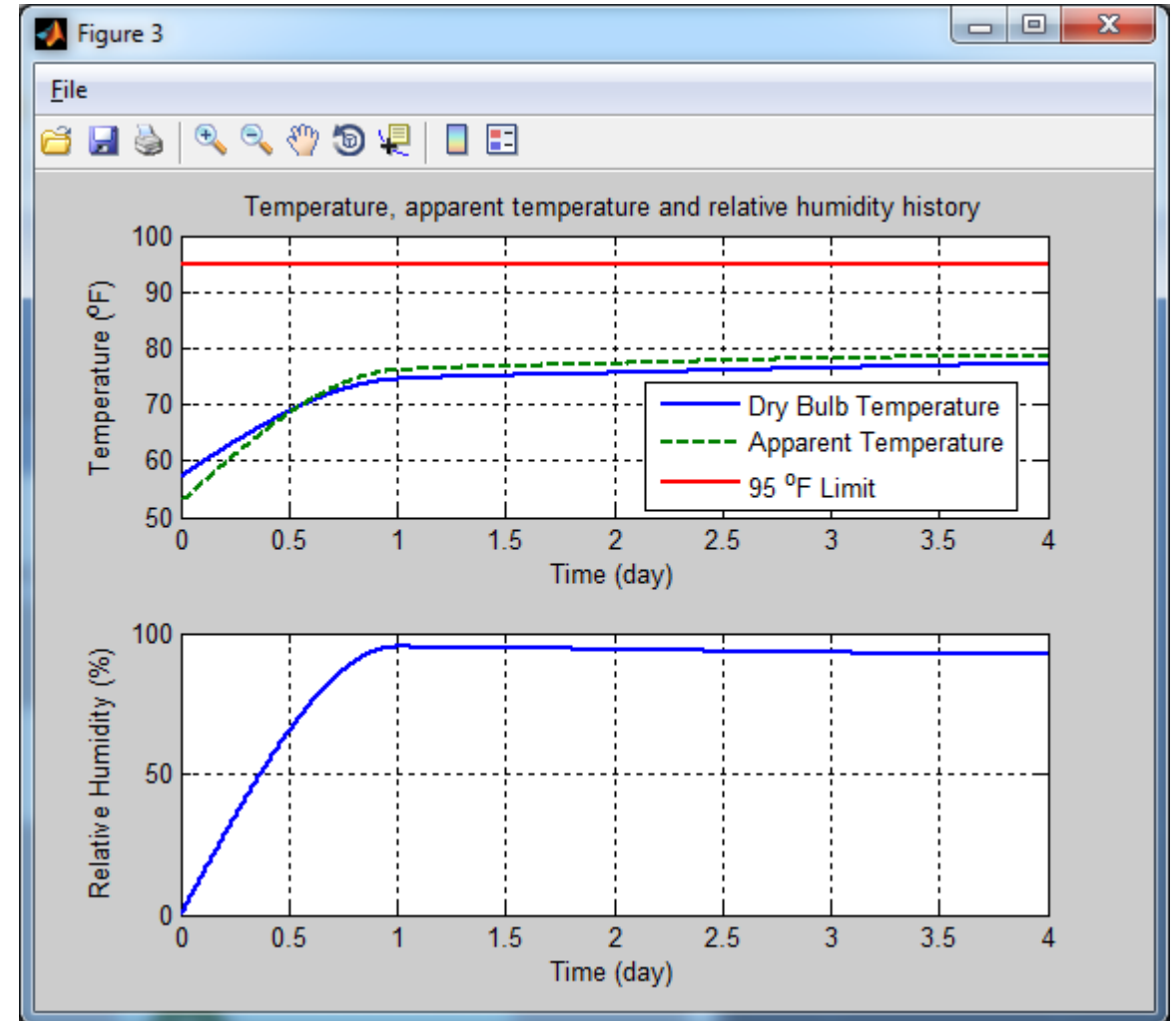
Temperature and condensation distribution maps

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

Refuge Alternative User Input Template

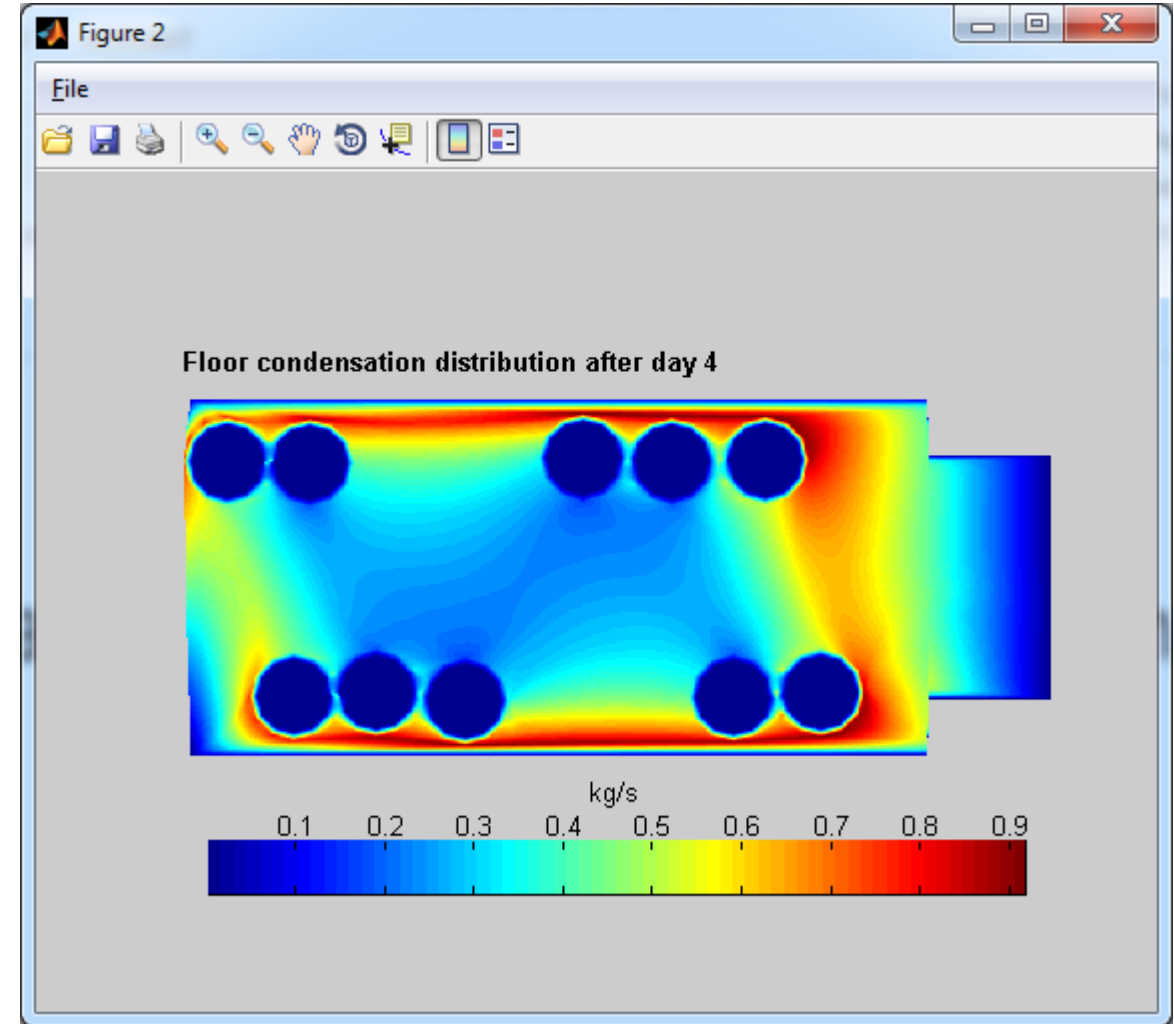
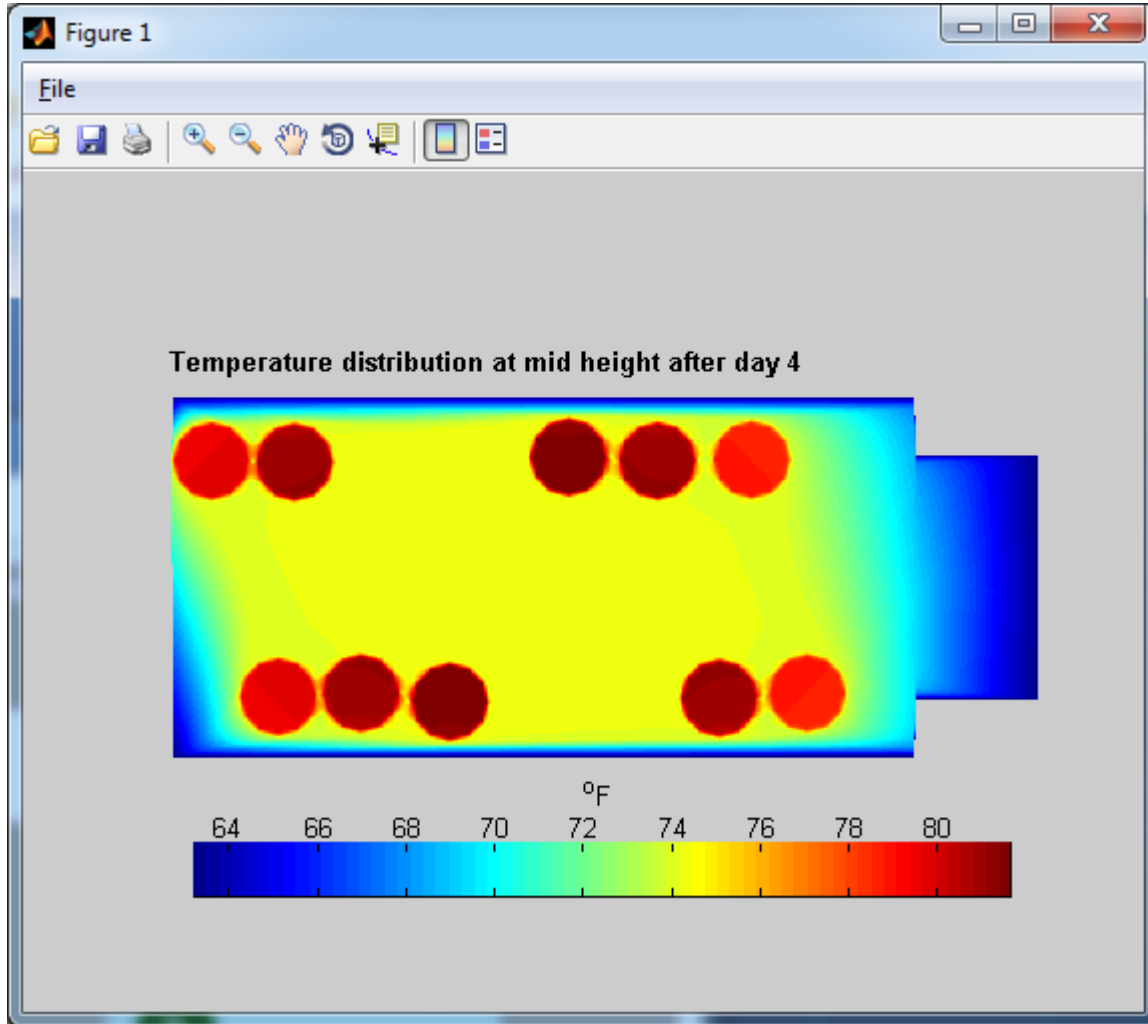
Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
1	0.84	0.48	1	1
2	0.3	2.39	1	1
3	1.51	0.51	1	1
4	0.97	2.38	1	1
5	2.23	0.44	1	1
6	3.19	2.42	1	1
7	4.41	0.47	1	1
8	3.91	2.39	1	1
9	5.12	0.51	1	1
10	4.67	2.40	1	1



Temperature and humidity vs. time

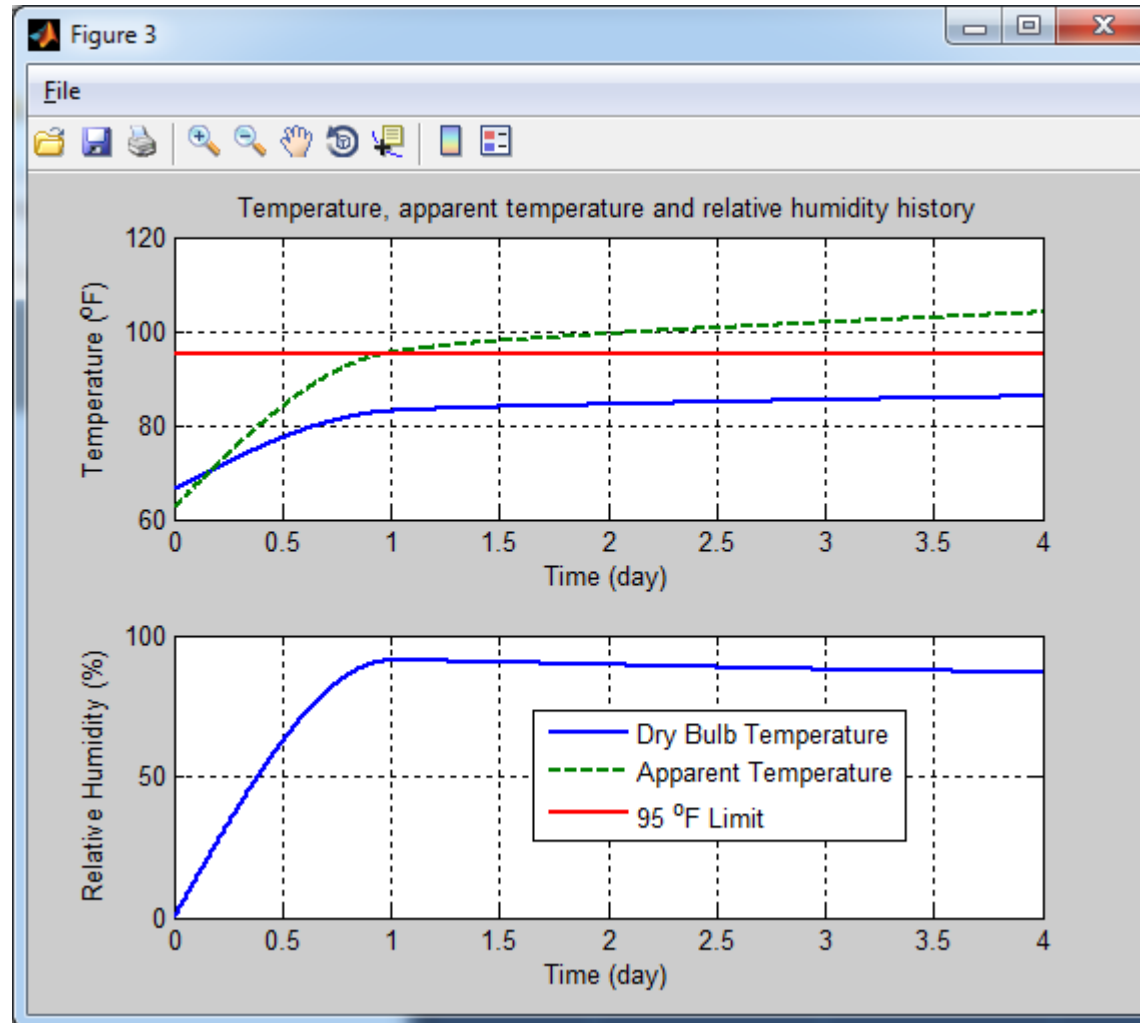
Example 2: 10-person RA, non-uniform distribution of occupants,
hanger-type CO₂ scrubber, 57.2 °F ambient temperature

Manually moved occupants



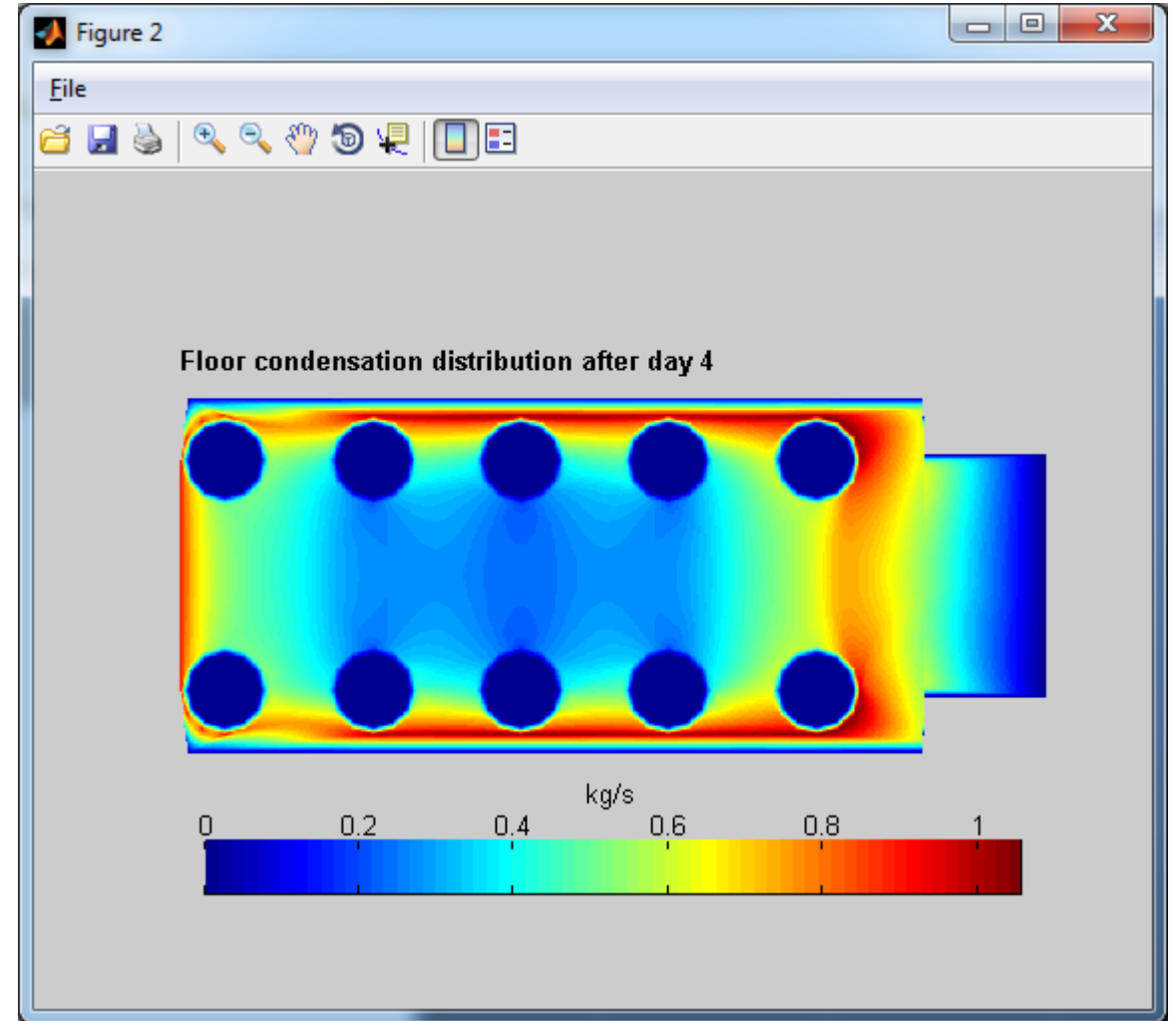
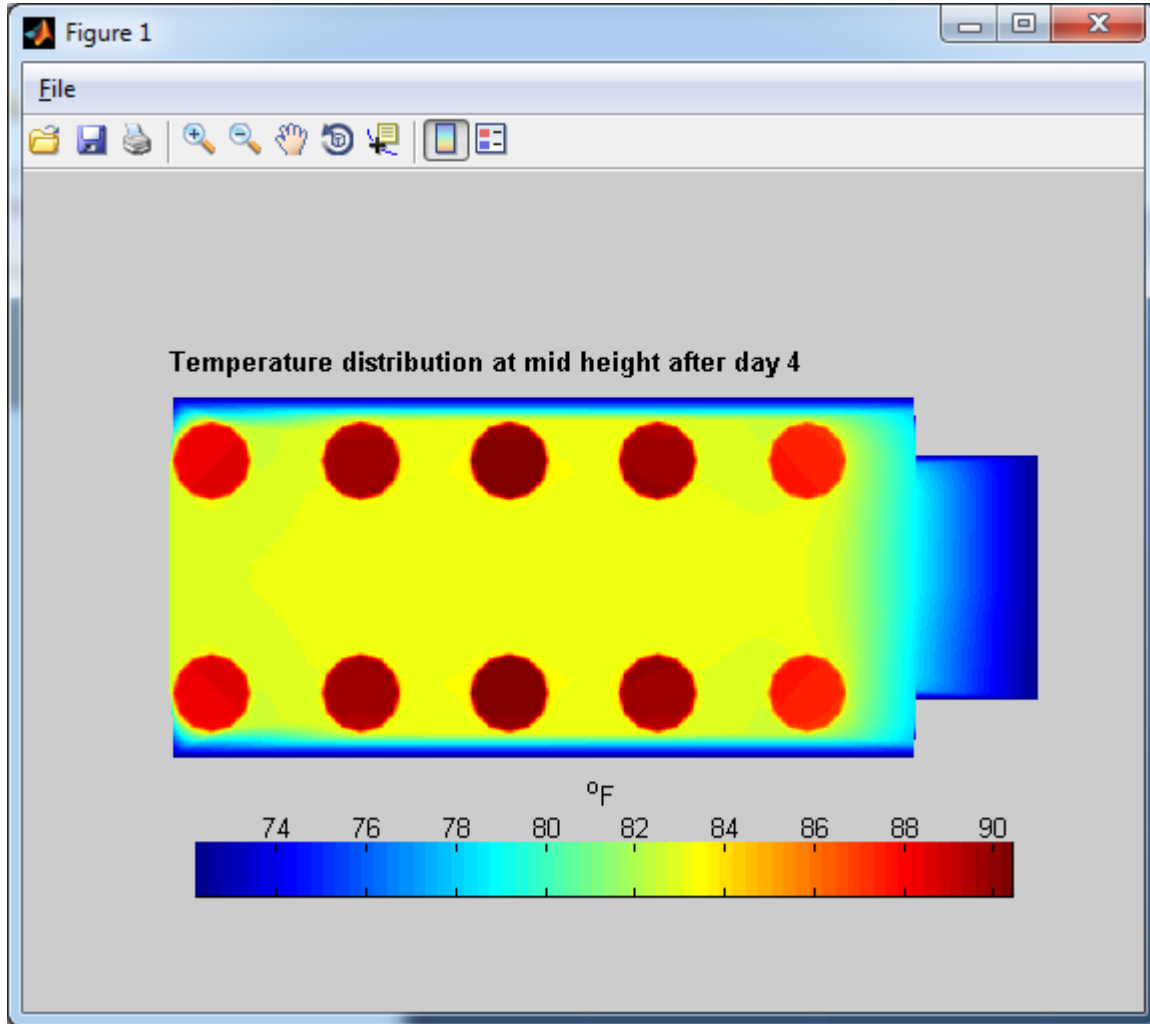
Temperature and condensation distribution maps

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, Ta > 95°F



Temperature and condensation distribution maps

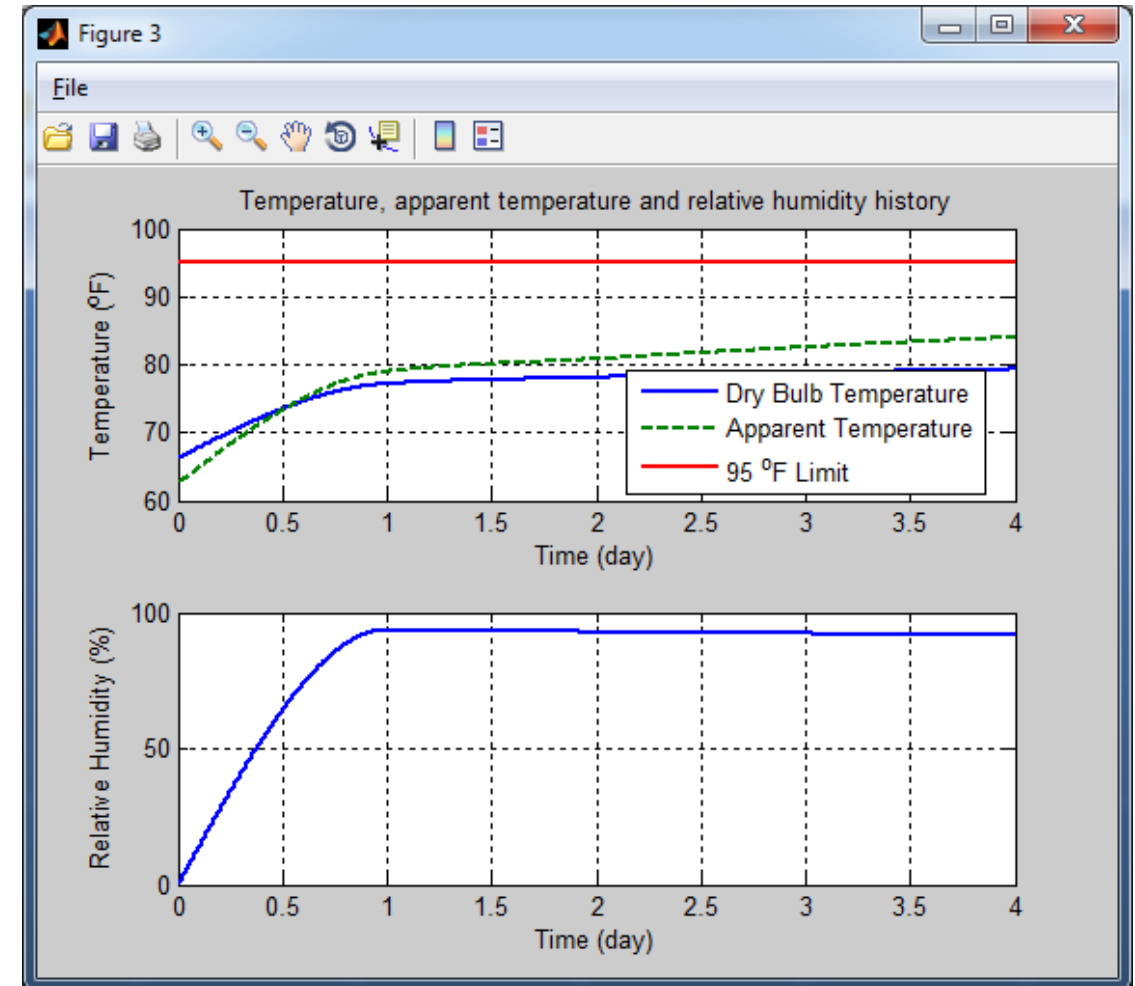
Example 4: 10-person RA, derated to 7-person occupancy, hanger-type CO₂ scrubber, 66.2°F ambient temperature

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

Refuge Alternative User Input Template

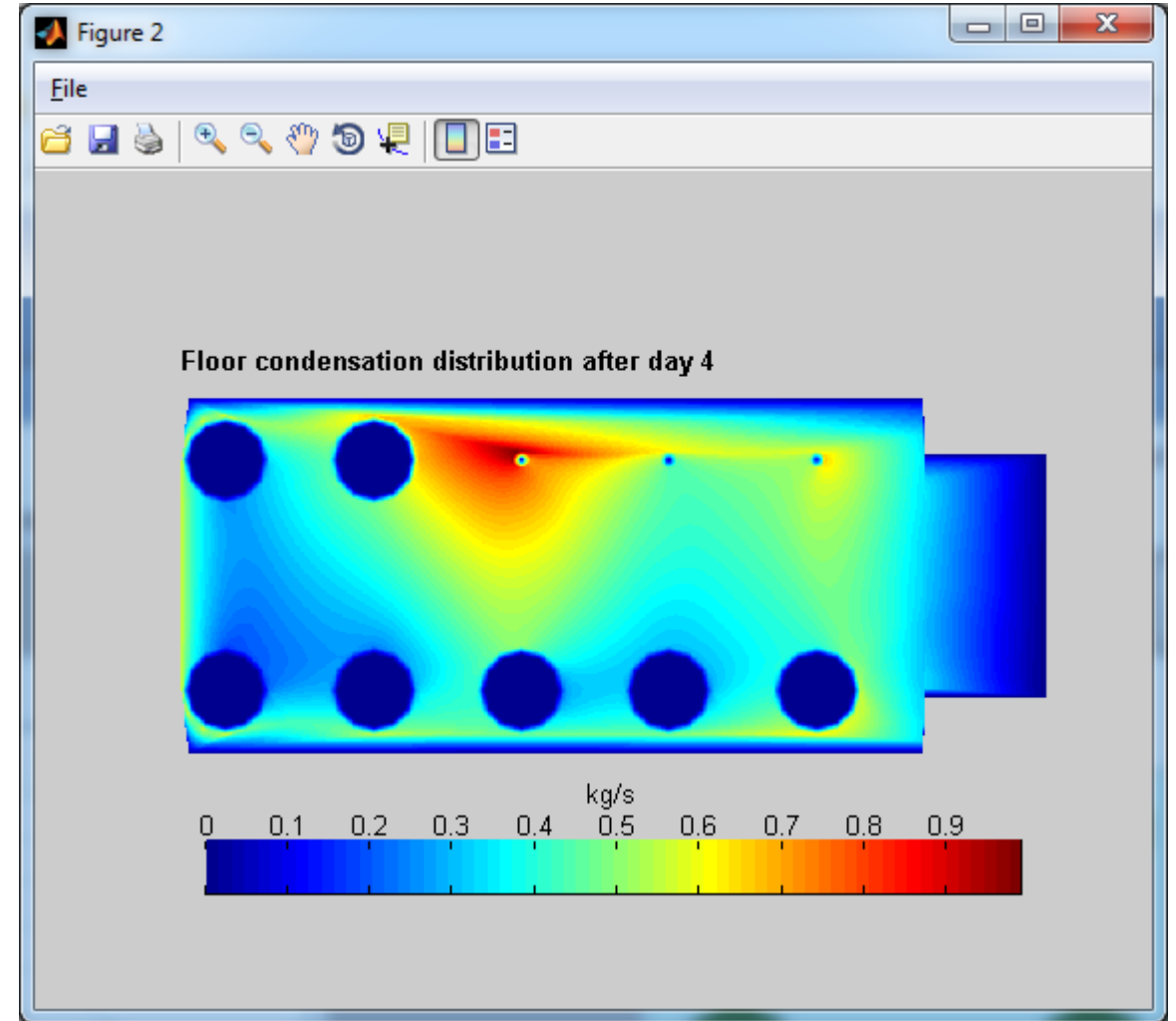
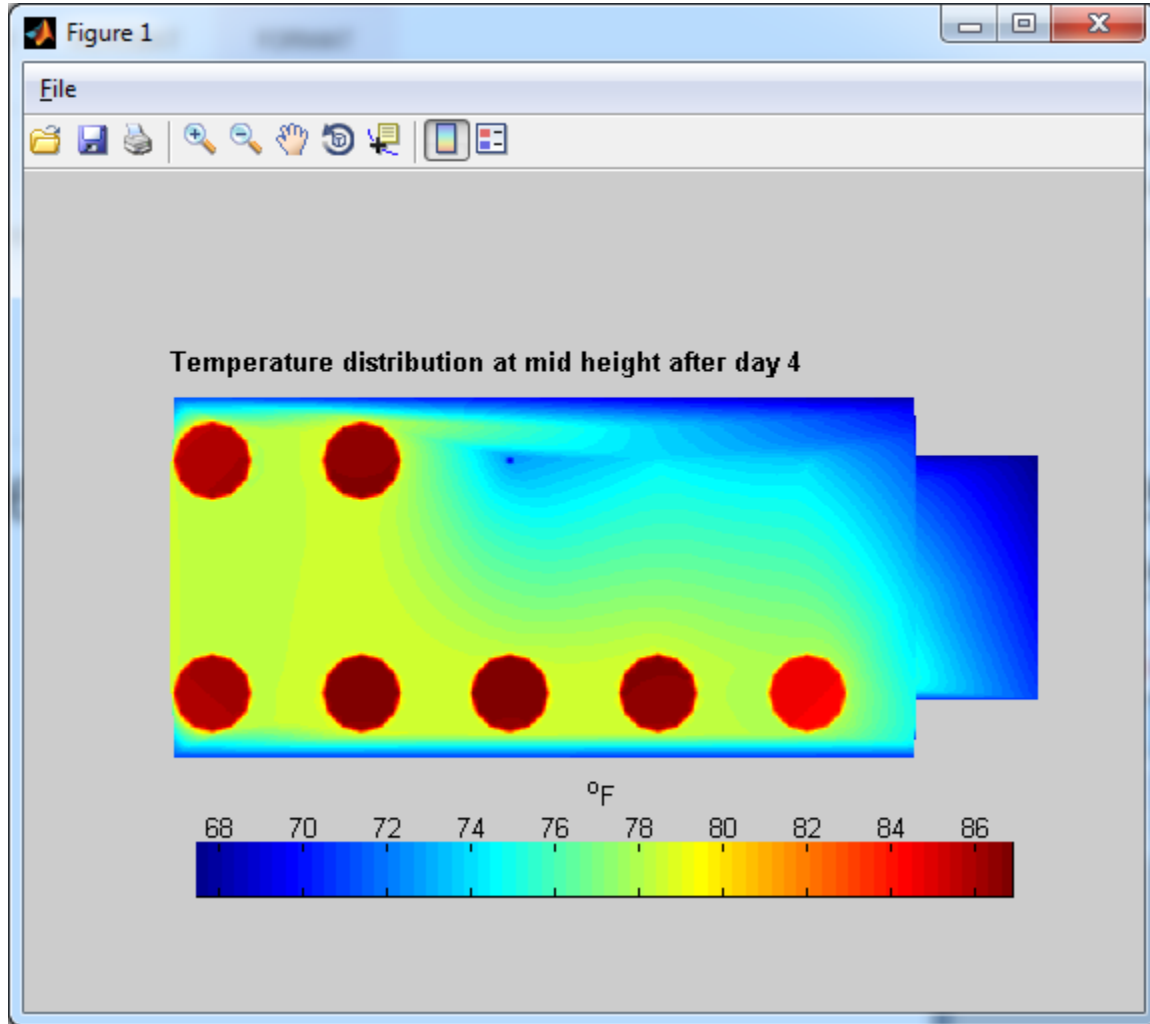
Index	X Position	Y Position	Surface Multiplier	Heat Dissipation Multiplier	Moisture Dissipation Multiplier
1	0.3	0.51	1	1	1
2	0.3	2.39	1	1	1
3	1.51	0.51	1	1	1
4	1.51	2.39	1	1	1
5	2.71	0.51	1	1	1
6	2.71	2.39	0	0	0
7	3.91	0.51	1	1	1
8	3.91	2.39	0	0	0
9	5.12	0.51	1	1	1
10	5.12	2.39	0	0	0

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

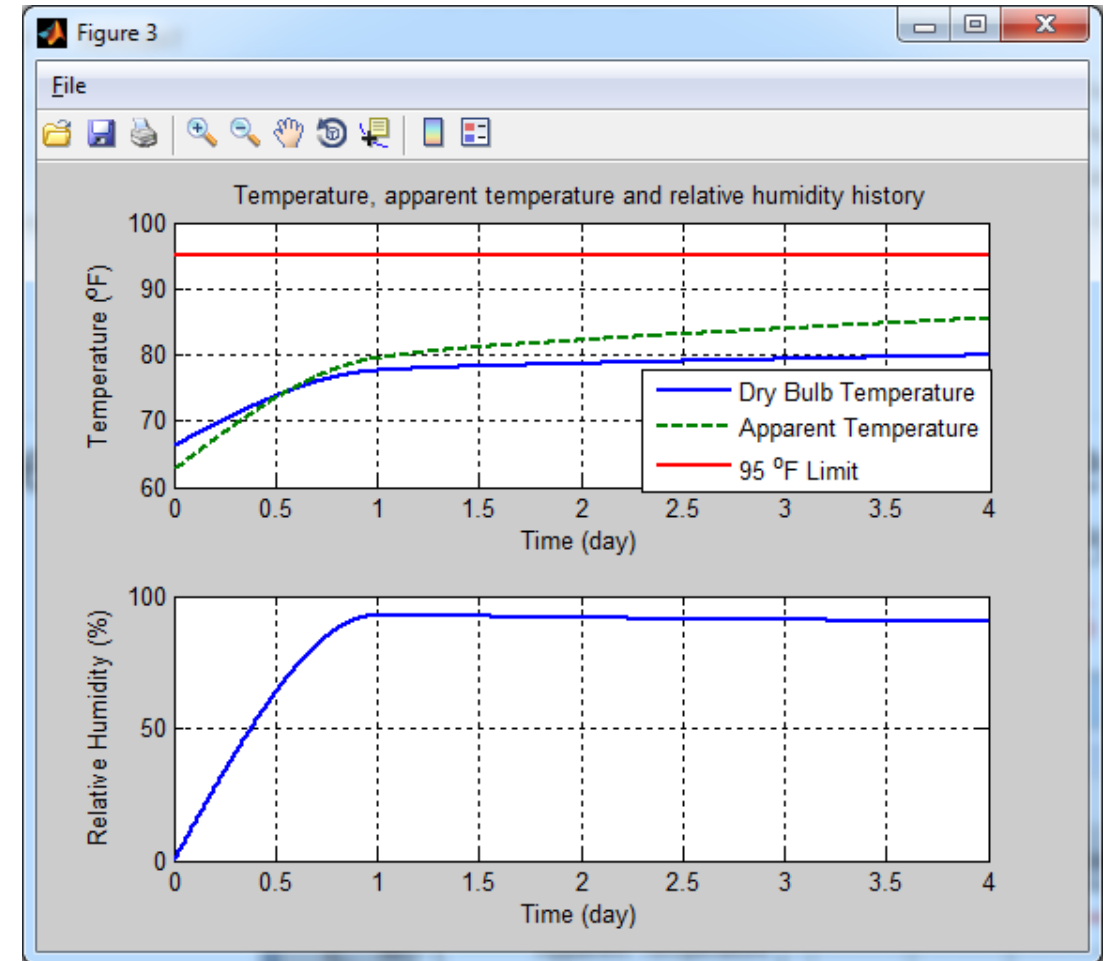
Reduced occupancy (10 to 7) from one end of RA space

Refuge Alternative User Input Template

Individual Human/Scrubber/Equipment Data

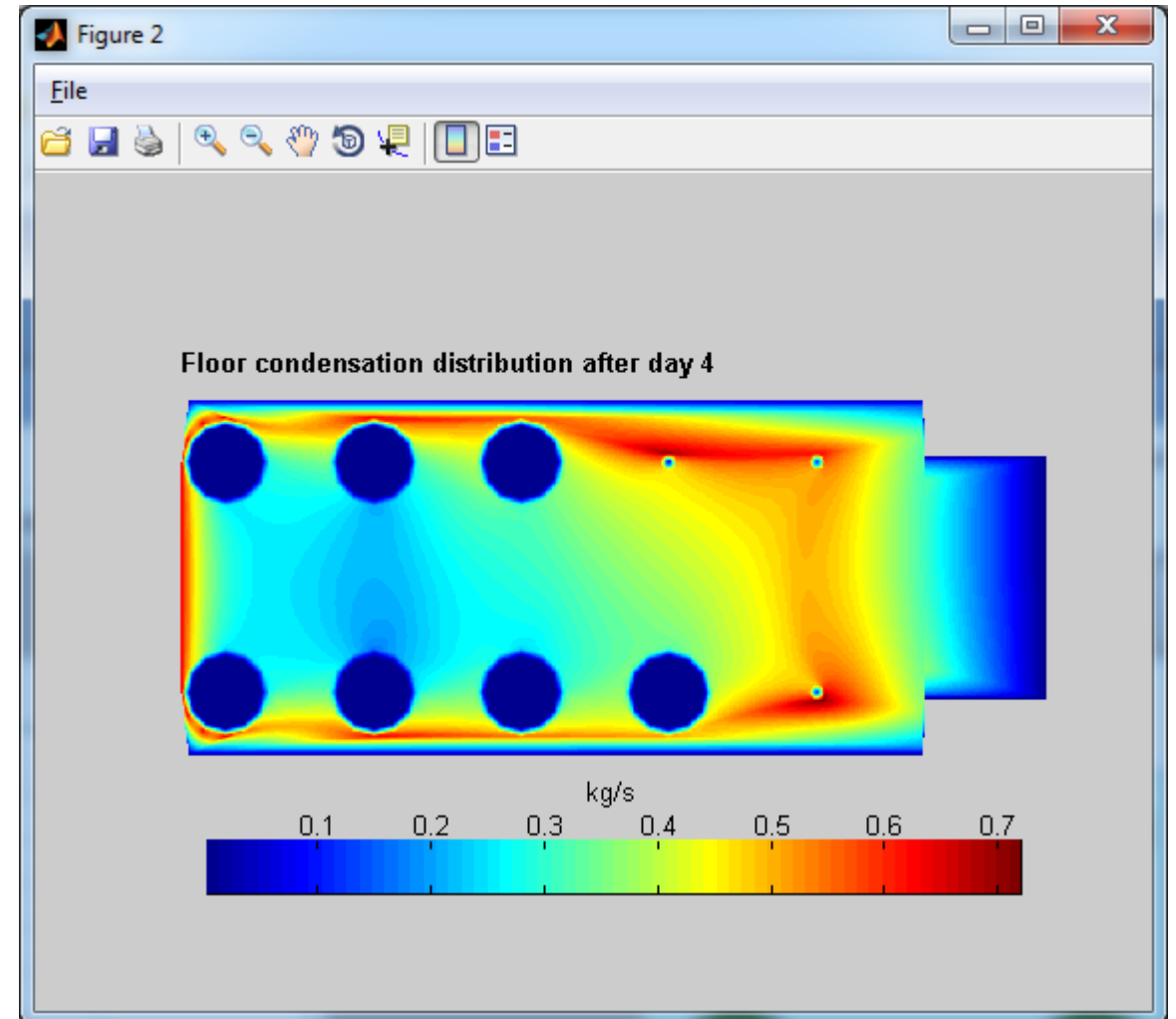
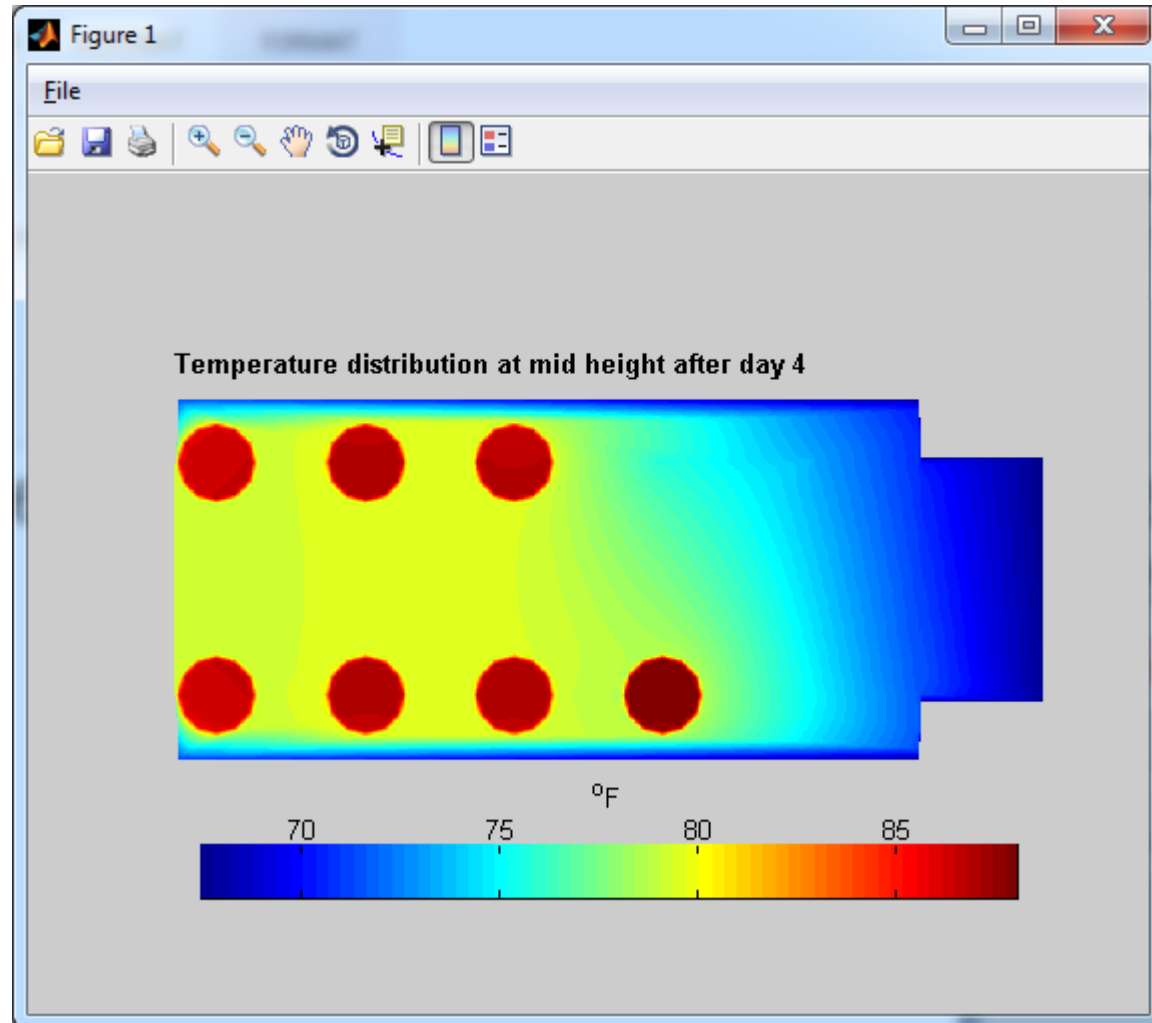
Index	X Position	Y Position	Surface Multiplier	Heat Dissipation Multiplier	Moisture Dissipation Multiplier
1	0.3	0.51	1	1	1
2	0.3	2.39	1	1	1
3	1.51	0.51	1	1	1
4	1.51	2.39	1	1	1
5	2.71	0.51	1	1	1
6	2.71	2.39	0	0	0
7	3.91	0.51	1	1	1
8	3.91	2.39	0	0	0
9	5.12	0.51	1	1	1
10	5.12	2.39	0	0	0

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

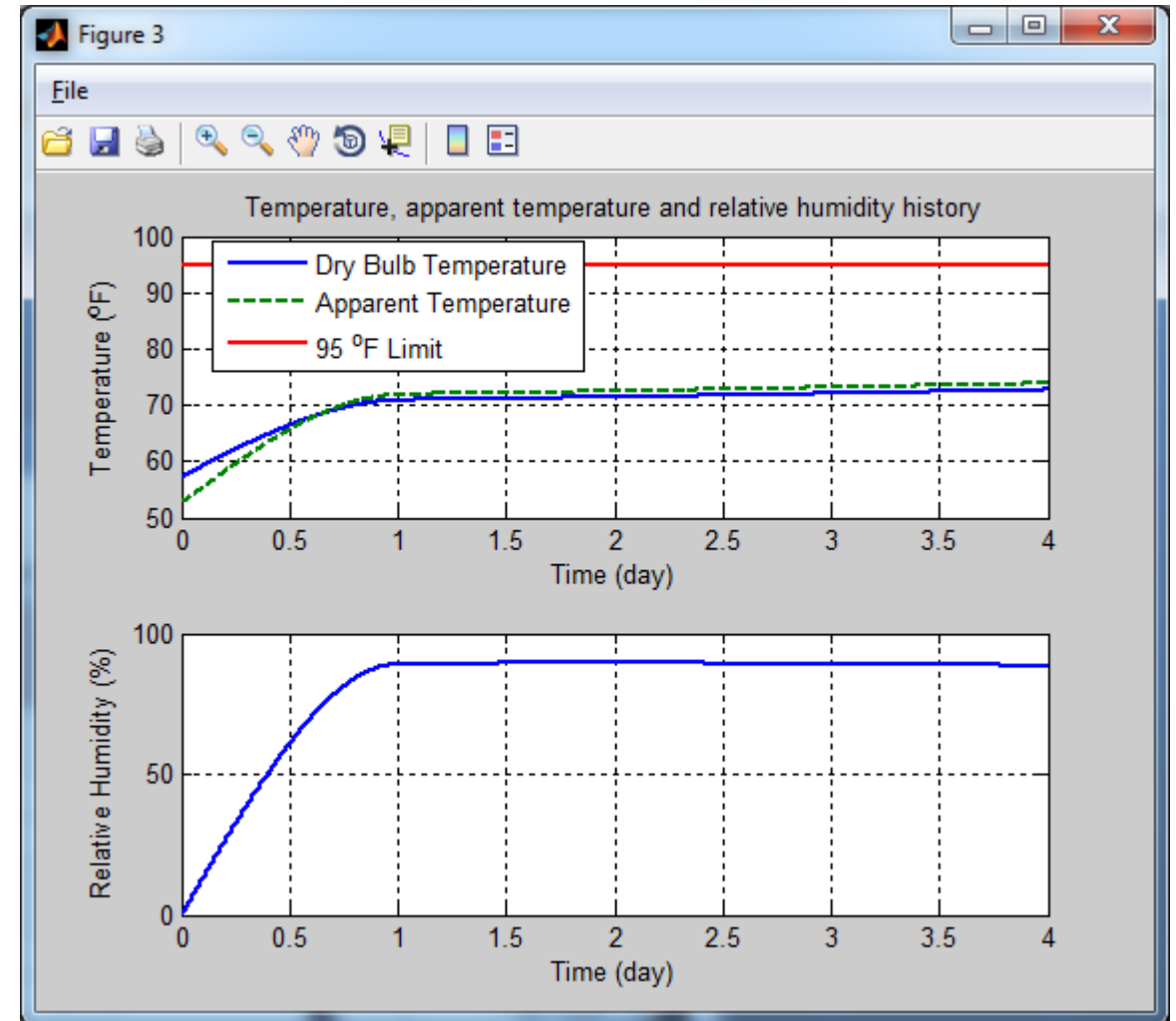
Example 6: 23-person RA, hanger-type CO₂ scrubber, 57.2 °F ambient temperature

Refuge Alternative User Input Template

Individual Human/Scrubber/Equipment Data

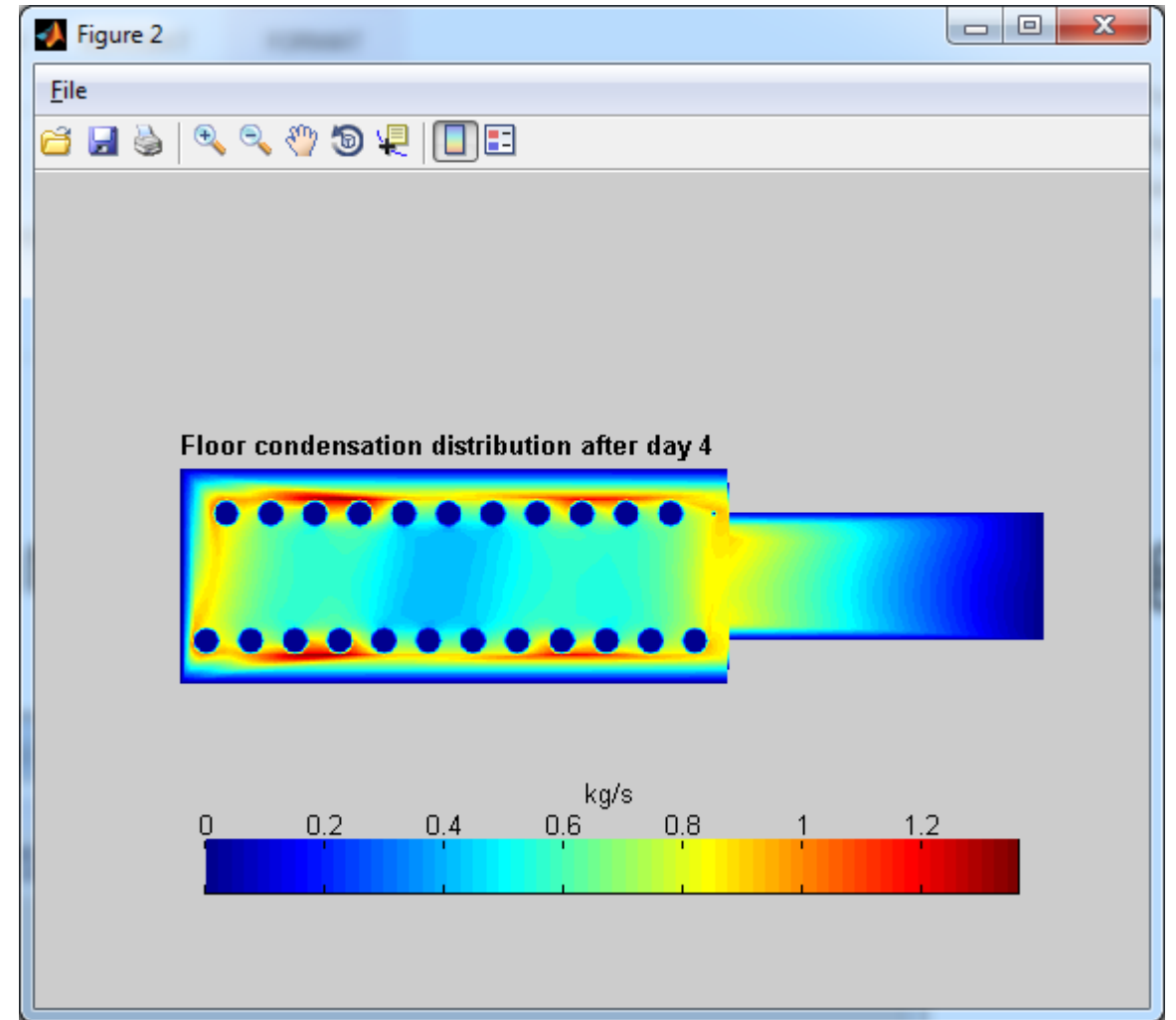
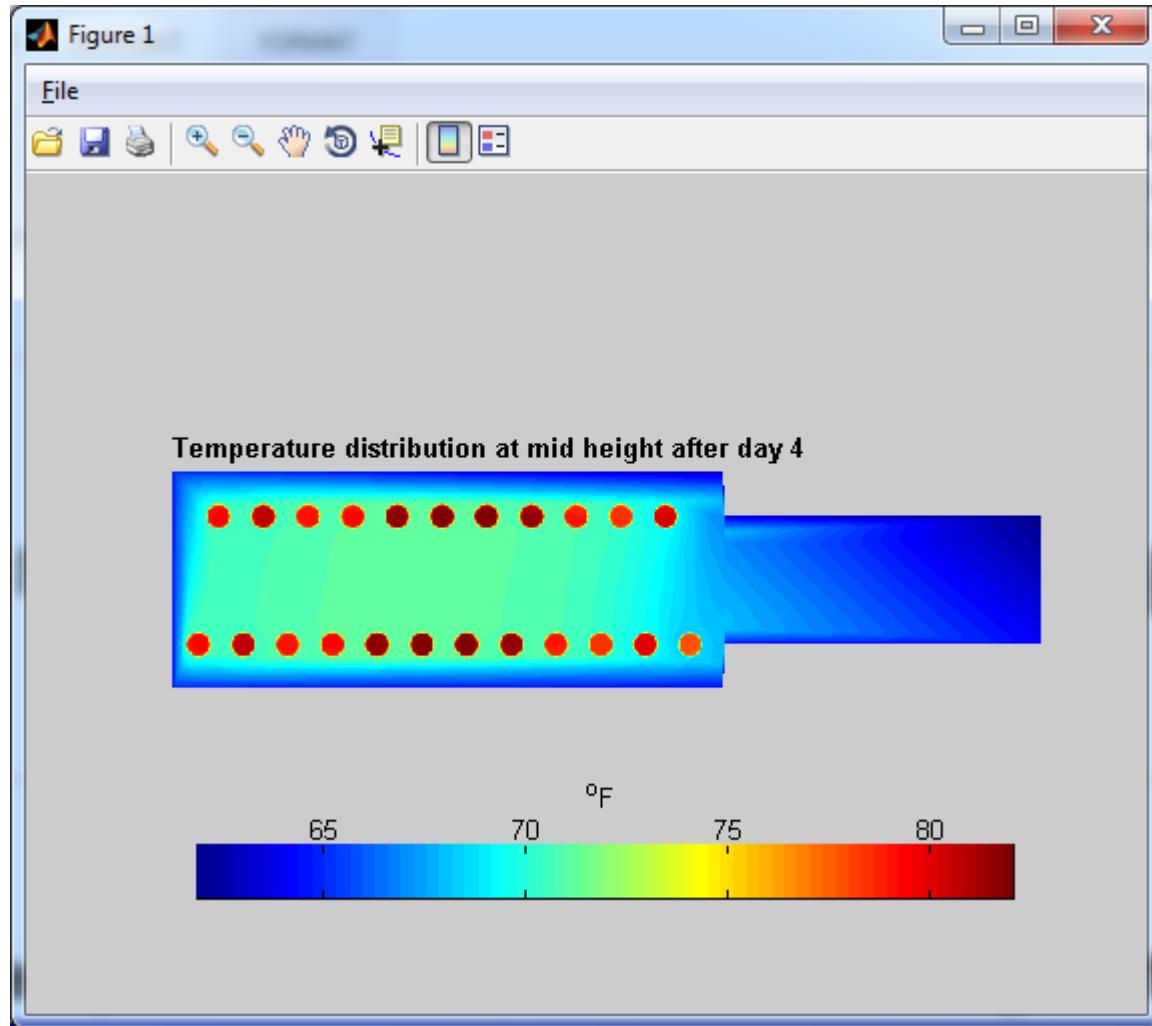
Index	X Position	Y Position	Surface Multiplier	Heat Multiplier
1	0.4318	0.7366	1	1
2	0.7747	2.921	1	1
3	1.1938	0.7366	1	1
4	1.5367	2.921	1	1
5	1.9558	0.7366	1	1
6	2.2987	2.921	1	1
7	2.7178	0.7366	1	1
8	3.0607	2.921	1	1
9	3.4798	0.7366	1	1
10	3.8227	2.921	1	1
11	4.2418	0.7366	1	1
12	4.5847	2.921	1	1
13	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

Buttons: 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

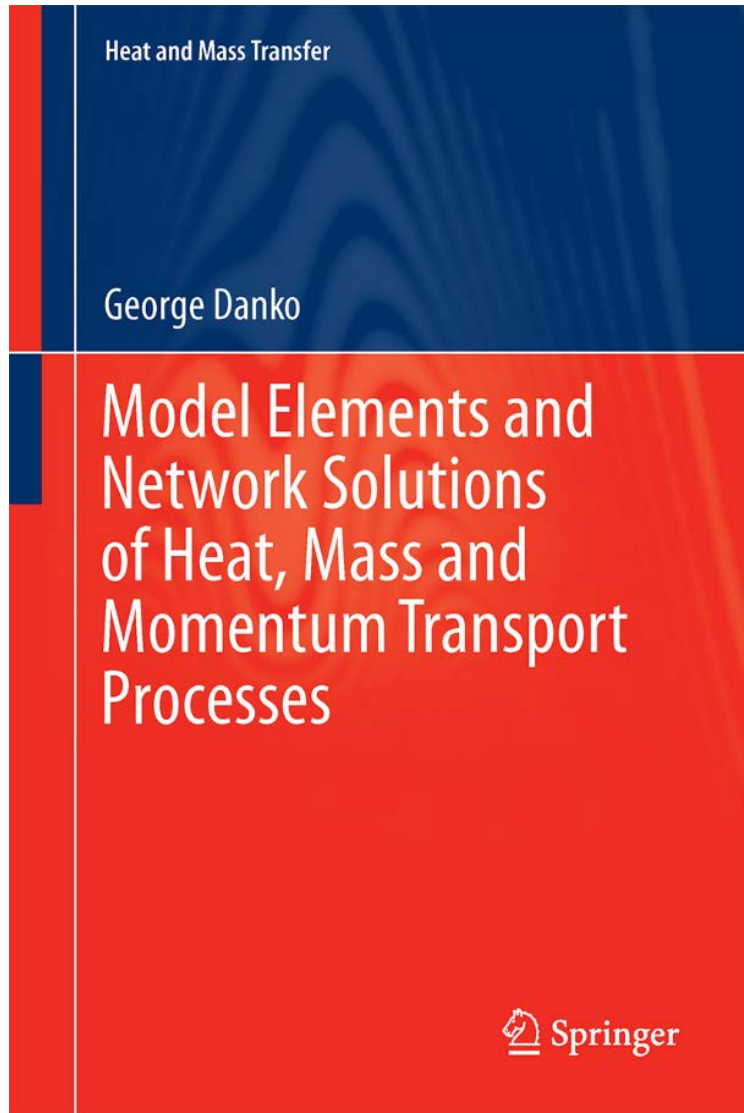
Conclusions and Recommendations

- UNR's universal RA model is easy to configure in a graphical environment
- Only the manufacturer's RA data, and some common data from the mine are needed to start the model simulation
- The model solves for temperature, humidity, condensation, and air movement within the RA space over 96 hours of occupation in a few minutes run time
- The universal model can rate the acceptability of any RA at any in situ mine condition without the need of further experiments with the RA at the mines
- The model has matched the 10-person RA measurement results for three different NIOSH experiments within a few percent
- More sets of NIOSH's experimental results for different RA types should be used for further verifications of the universal thermal model before commercialization to mines
- The Ventsim ventilation model can predict the T_{air} ambient temperature around all RA locations with the known location of a fire. The UTHA simulation tool can then predict RA temperatures increased due to the fire. This information can be used to guide rescue operations
- For distribution, the universal thermal model is integrated into the Ventsim Visual mine ventilation and climate software which has customer support and thousands of licensed users
- Chasm Consulting, the vendor of the Ventsim software, is committed to market the UTHA software once the universal RA model is sufficiently verified against additional measurement results.

Thank You

Question?

The Computational Energy Dynamics (CED) Model



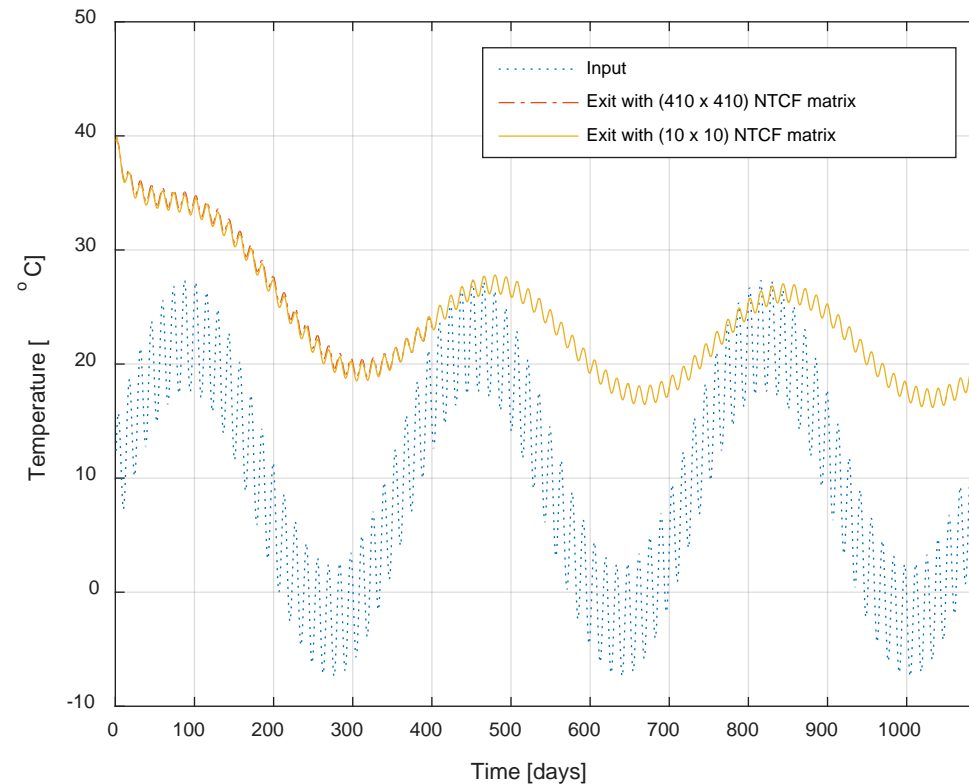
A new modeling tool is developed for the solution of large-scale, coupled, flow, heat, moisture, and contaminant transport problems. **CED is used to solve tasks in mine ventilation;** geothermal energy recovery; nuclear spent fuel repository or ventilated, interim storage facility design; and **refuge shelter studies** for trapped miners.

A book deals with the CED transport model elements:

<http://www.springer.com/gp/book/9783662529294>

Thermal Transients Simulation Underground

Input and simulated output air temperature result at 3,000 m downstream from input from modeling the thermal flywheel effect in the strata heat with MULTIFLUX



A long thermal history time may be necessary to include in the thermal model of the strata to adequately incorporate the thermal flywheel effect in the temperature evaluation in long drifts from the intake which varies with time