

# MacroFlo + ApacheHVAC: Passive downdraft cool towers + thermally stratified zones and atrium



**INTEGRATED  
ENVIRONMENTAL  
SOLUTIONS**

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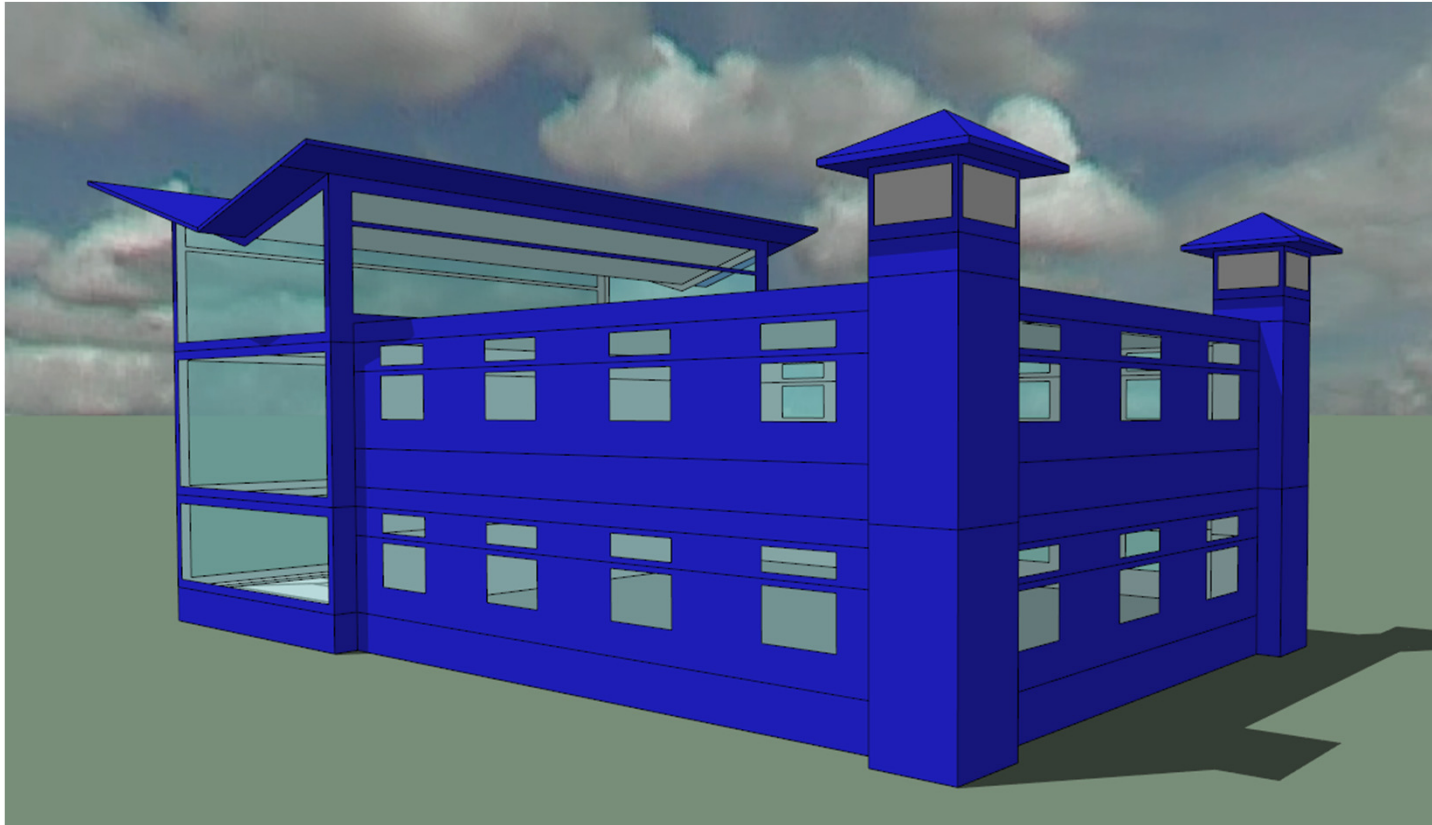
[timothy.moore@iesve.com](mailto:timothy.moore@iesve.com)

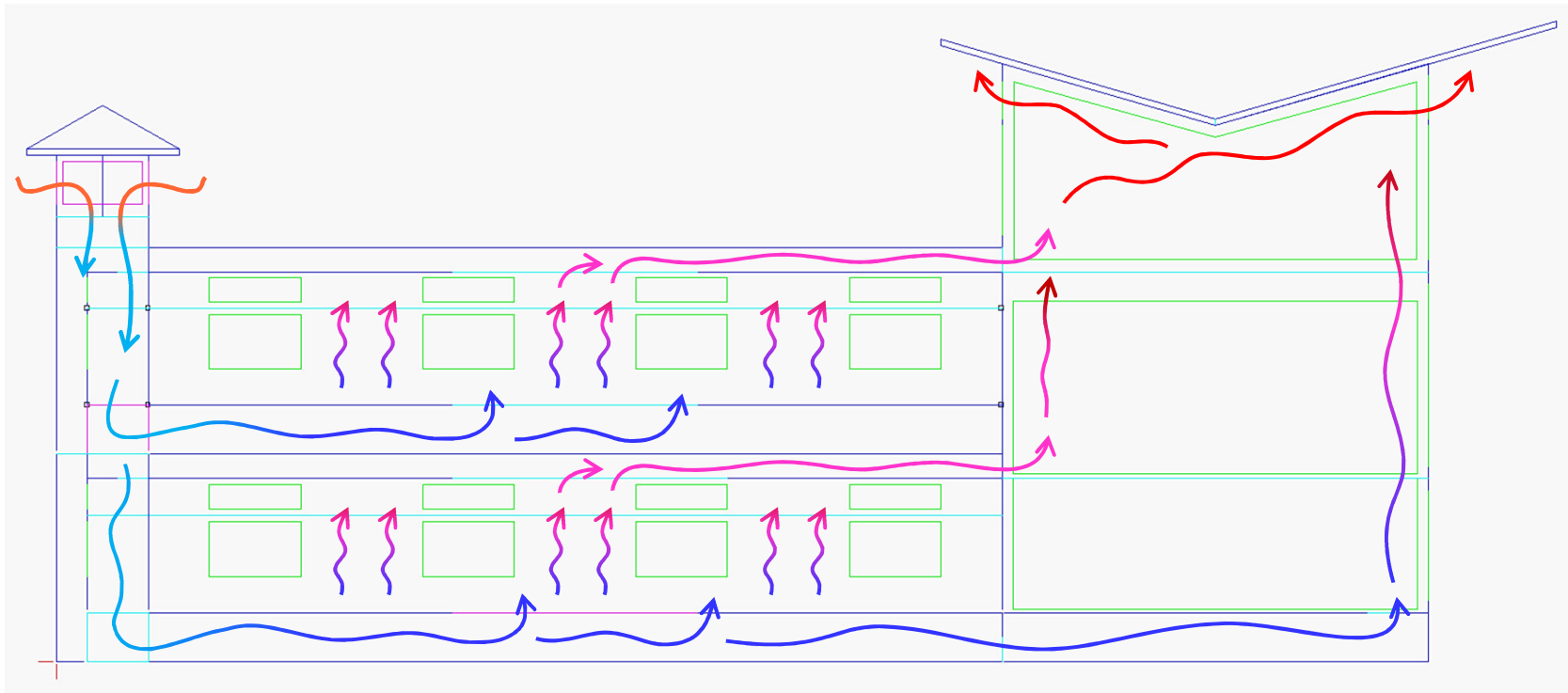
**March 2013**



## **Passive downdraft cool towers + thermally stratified zones, atrium**

- ApacheHVAC for cooling coils or evaporative cooling and heating coils
  - Built as proof of concept for much larger building using the same system
  - Fans are optional for assist in the actual building, but not required
  - Example model is fully buoyancy driven (no fans) to test design approach
- Buoyancy-driven air movement through building modeled via MacroFlo





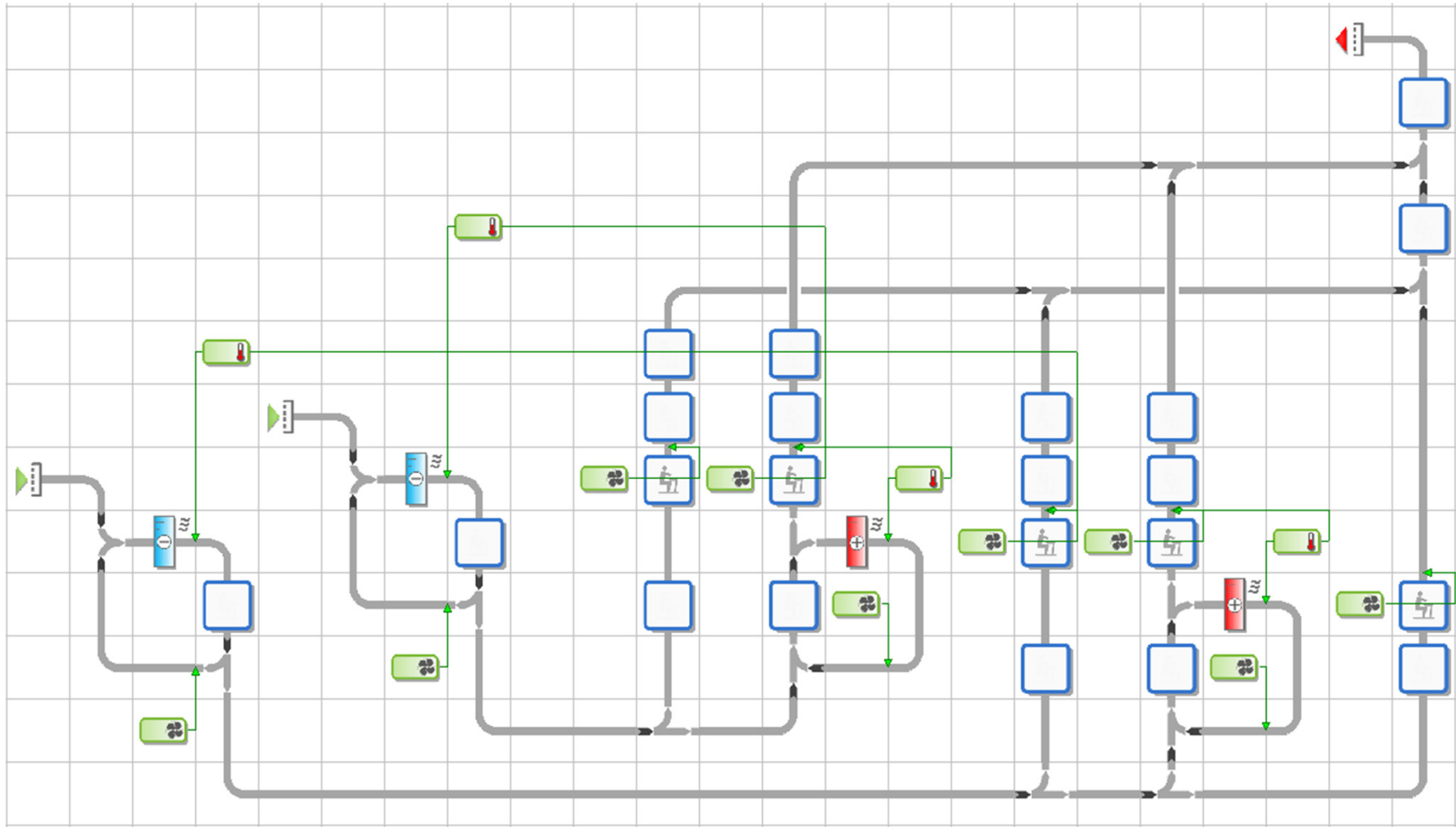
- Two downdraft towers: both have controllable inlets; one has wind baffles.
- UFAD supply air plenums
  - 1<sup>st</sup> floor provides example of controlled vent/cooling diffusers; heat by room units.
  - 2<sup>nd</sup> floor uses controlled inlets from towers to plenum; heat by coils in plenum.
- Occupied & stratified zones with typical internal gains
- RA plenums discharge to atrium
- Outlets placed high on atrium façades controlled to open only on downwind side



## Passive downdraft cool towers

Complete network with all zones and nodes included.

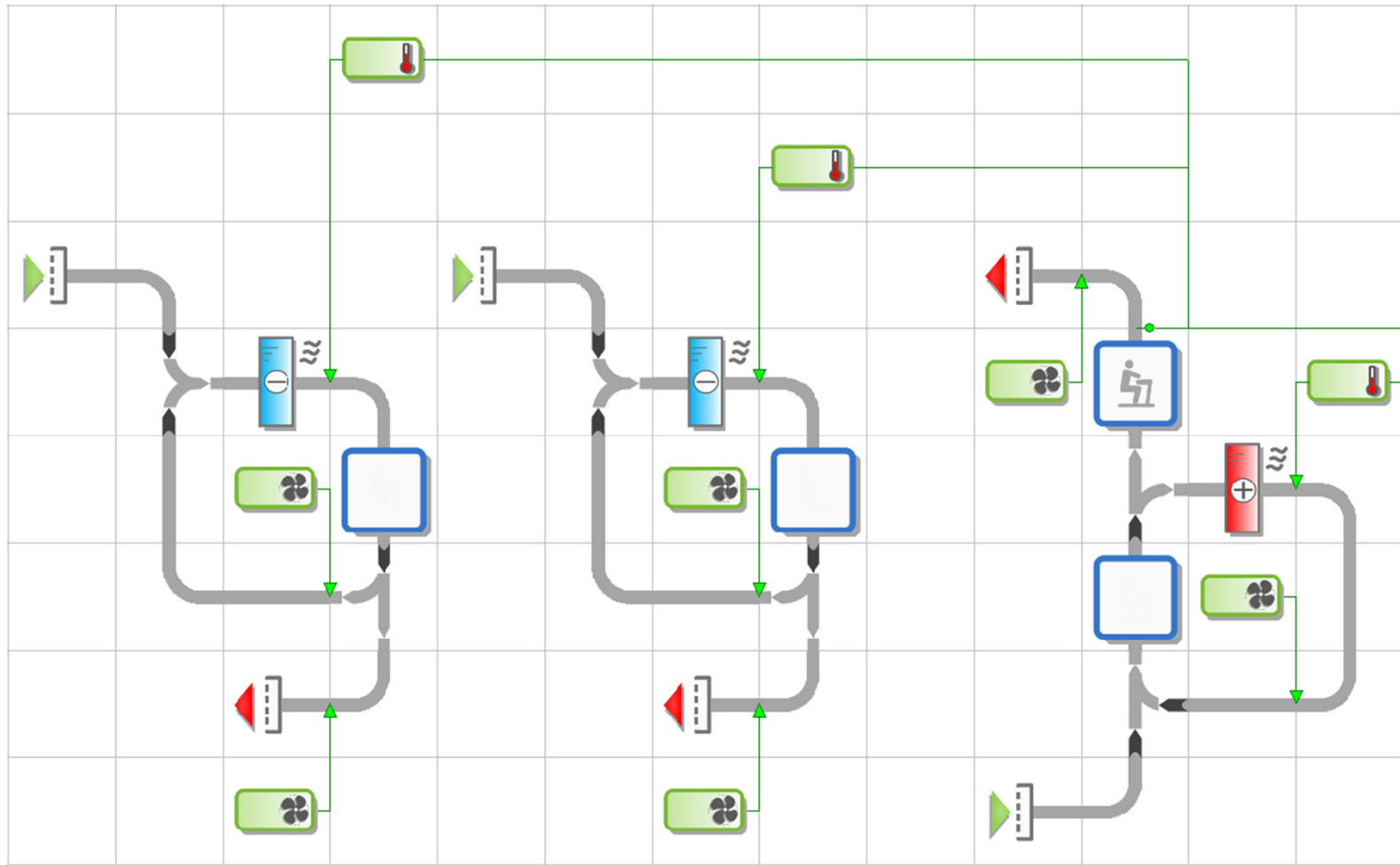
- Facilitated adding damper sets and heating coils where needed.





## Passive downdraft cool towers

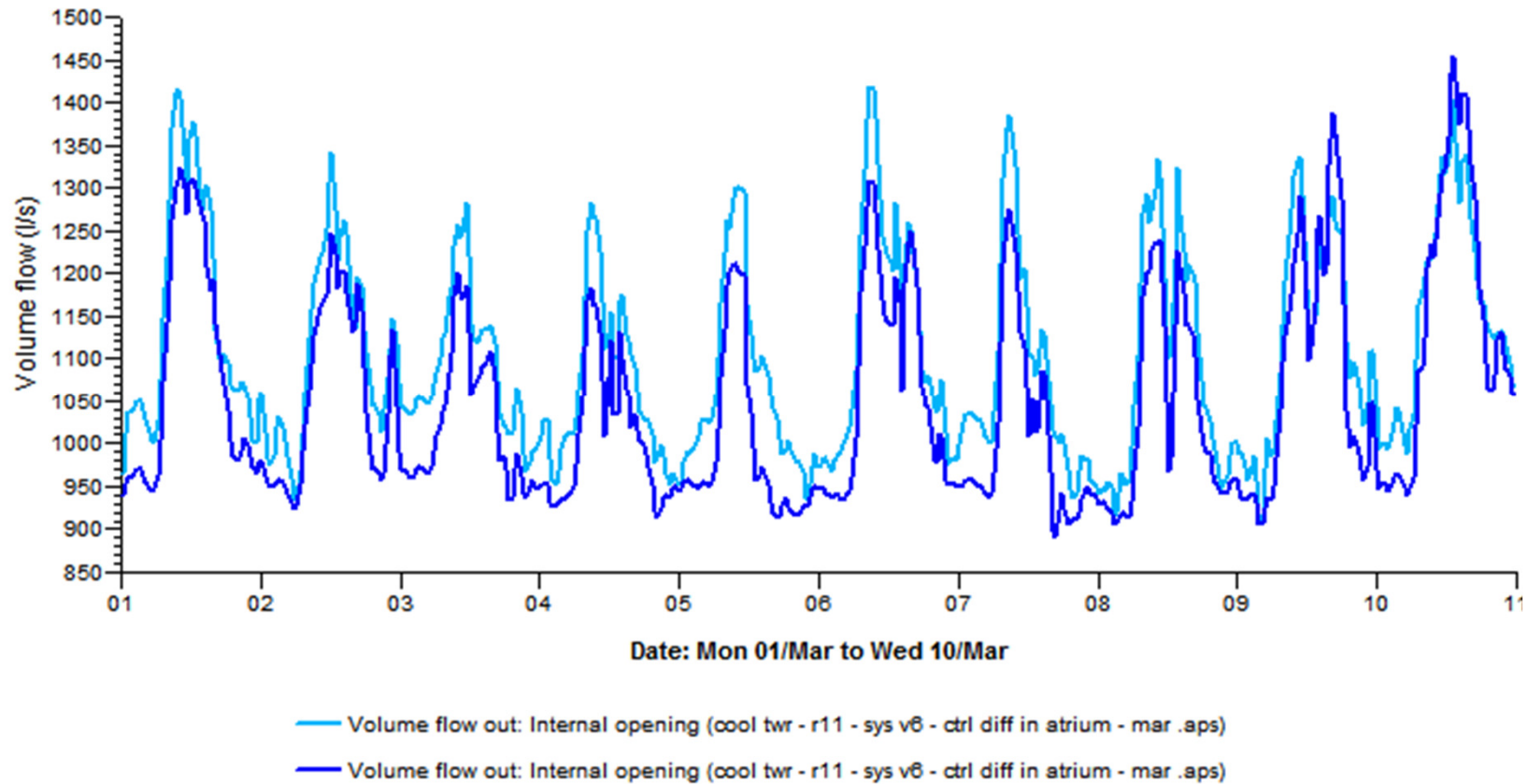
Minimal network — reduced to just the necessary zones and nodes.





## Passive downdraft cool towers

### Confirming downdraft flow between cells in cool towers

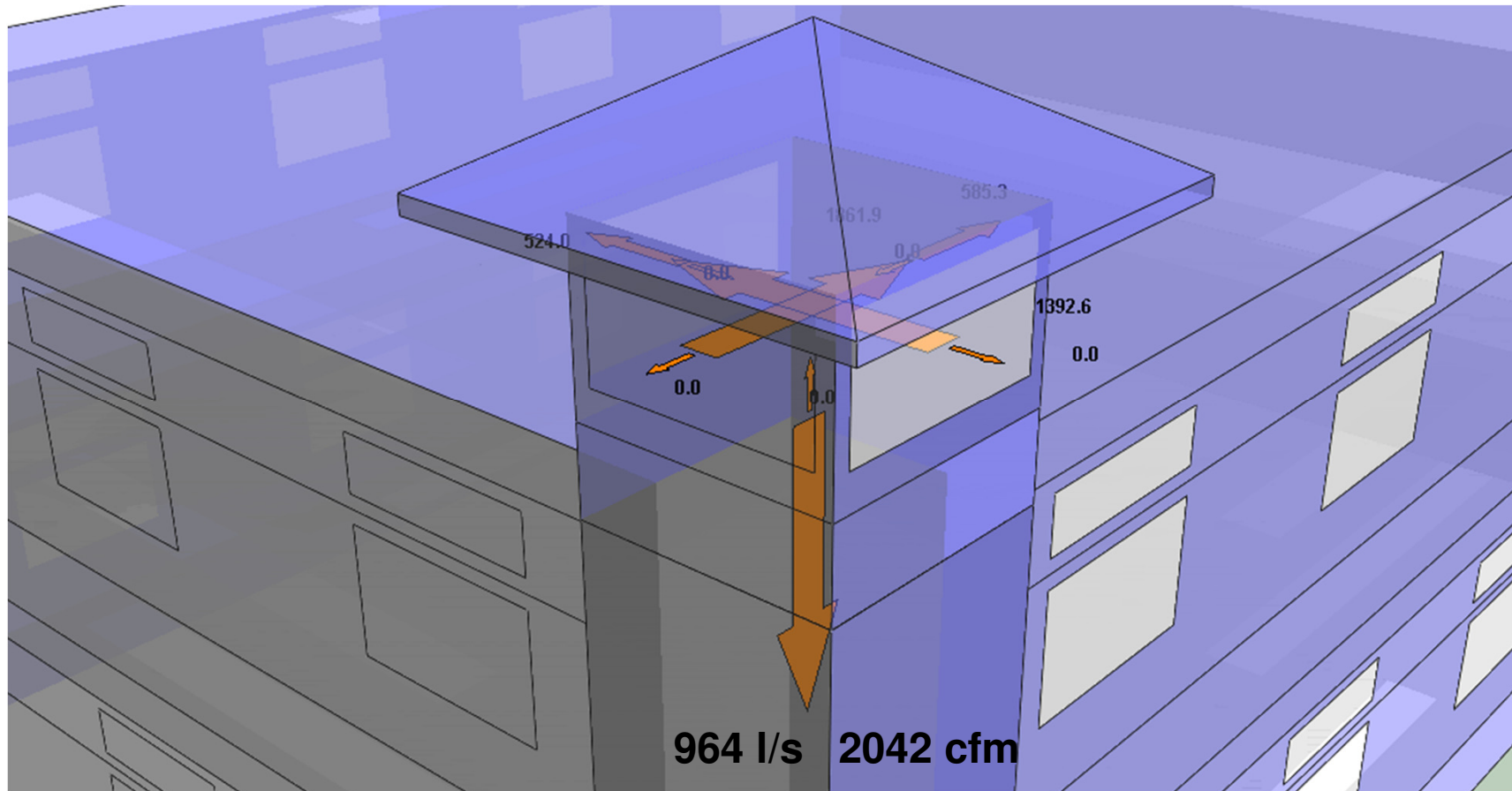


- Passive downdraft outflow from cooling coil cell of the tower (North and South towers shown) to the next cell or tower segment below.



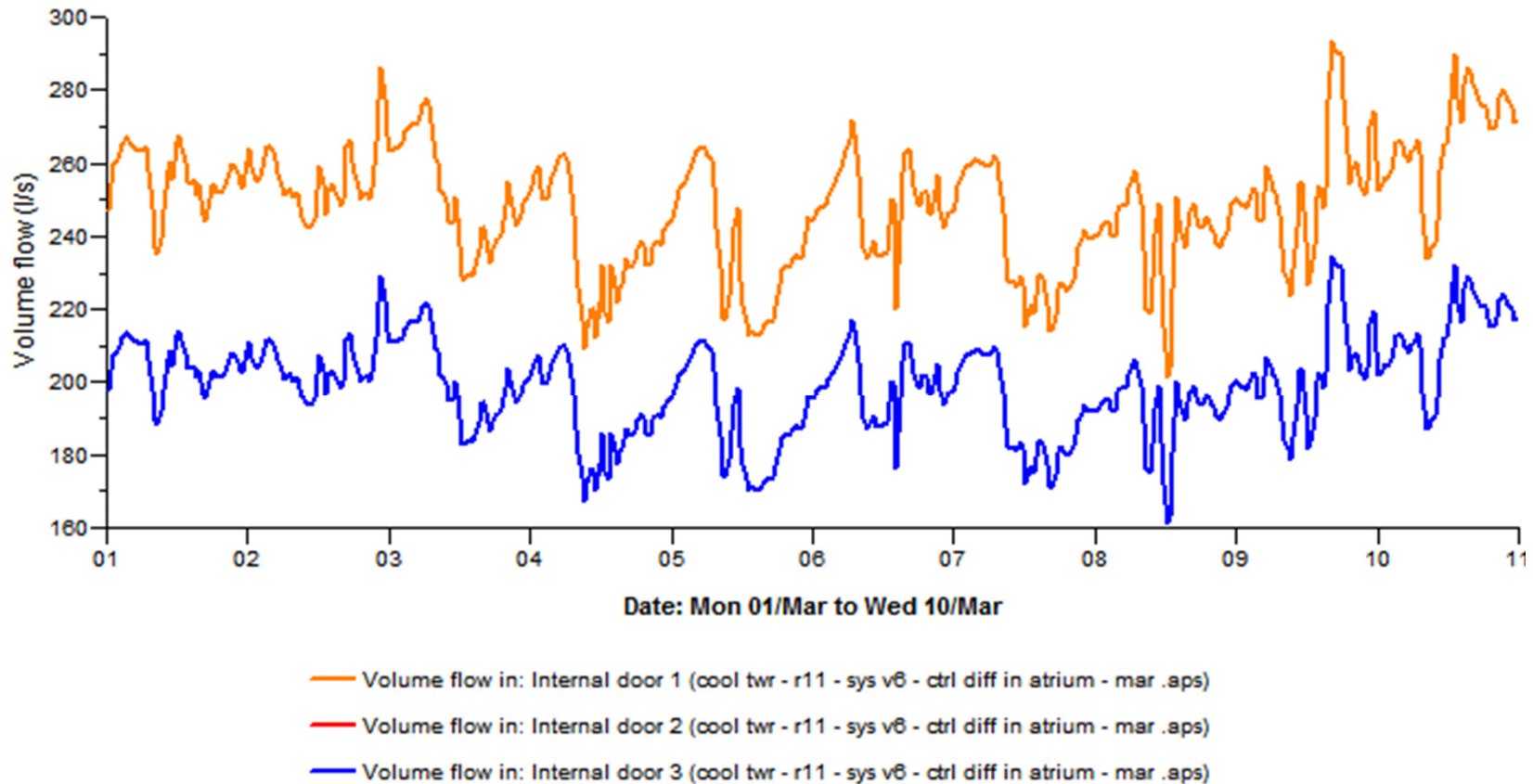
## Passive downdraft cool towers

Confirming flow into the towers and the majority of the flow down from there



- Passive downdraft outflow from cooling coil cell of the tower (North and South towers shown) to the next cell or tower segment below.

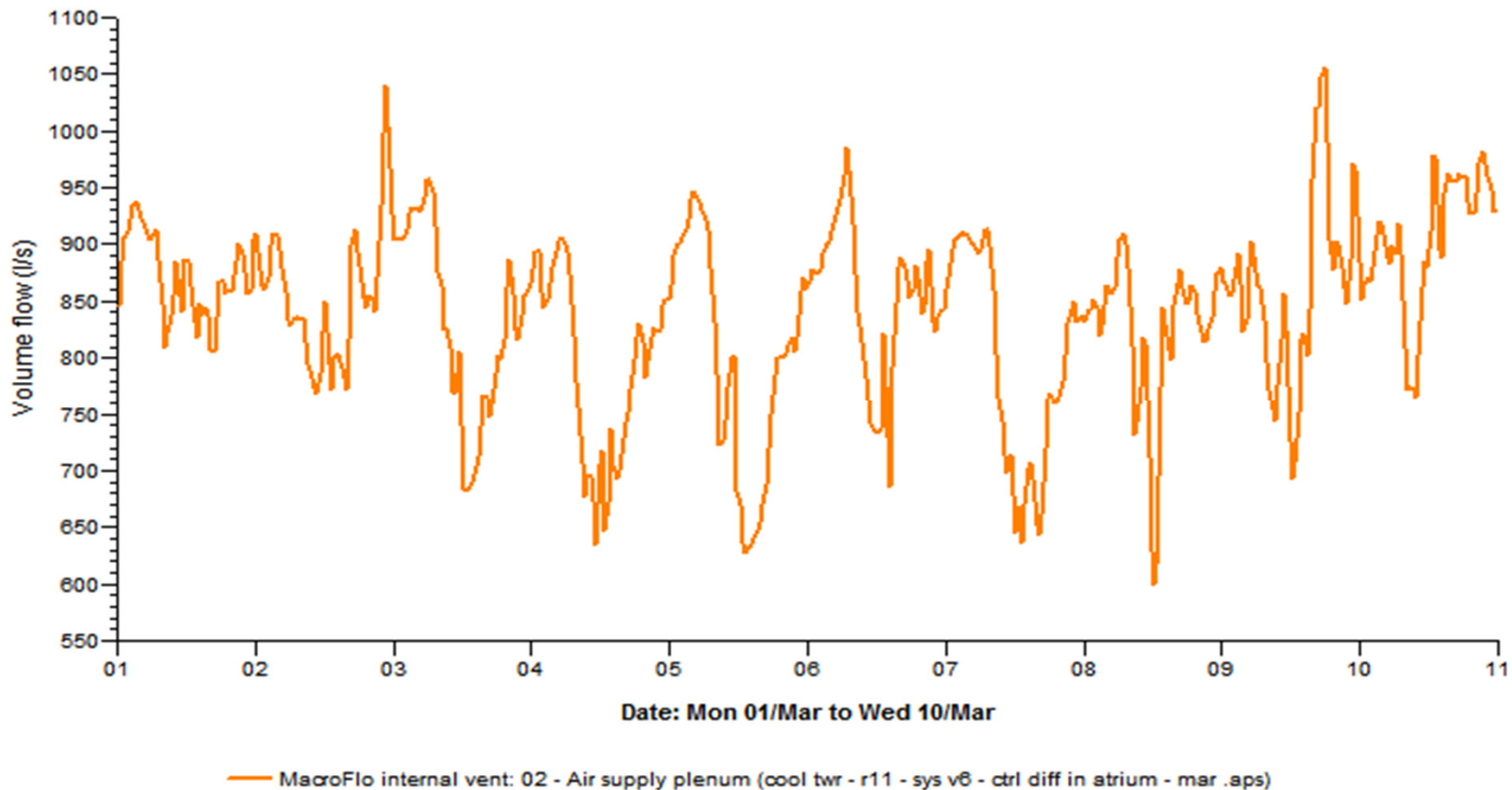
## Confirming flow at controlled floor diffusers



- Flow at two controlled discharge dampers in the UFAD supply plenum (controlled diffusers in MacroFlo are “doors” with formula profiles).



## Confirming flow through inlet dampers on 2<sup>nd</sup>-floor UFAD plenum

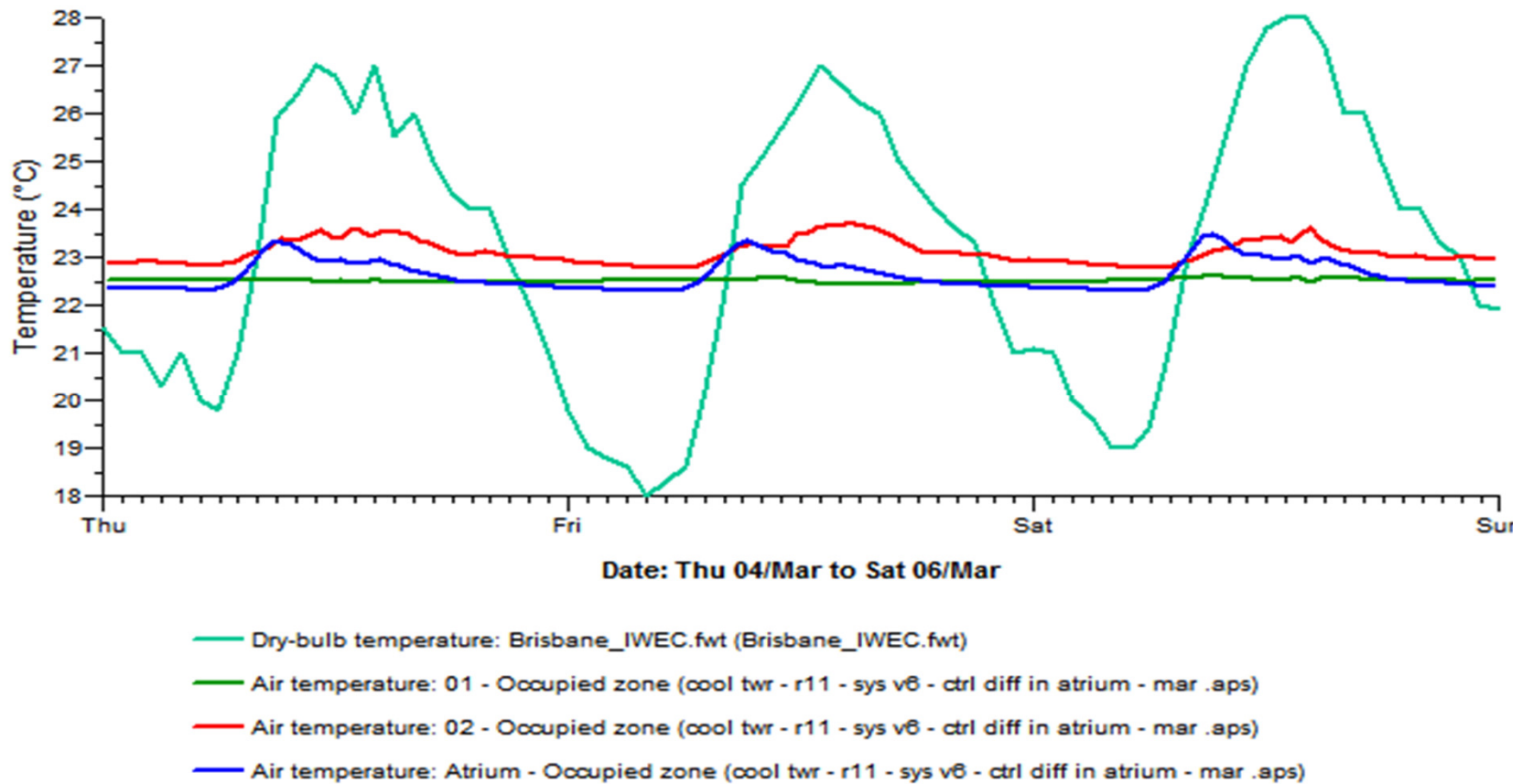


- Flow into the 2<sup>nd</sup>-floor UFAD plenum is controlled by dampers at the connection to the cool towers so that plenum can be heated in winter.



## Passive downdraft cool towers

Maintaining cooling setpoint (23°C +/- 1°C) in summer

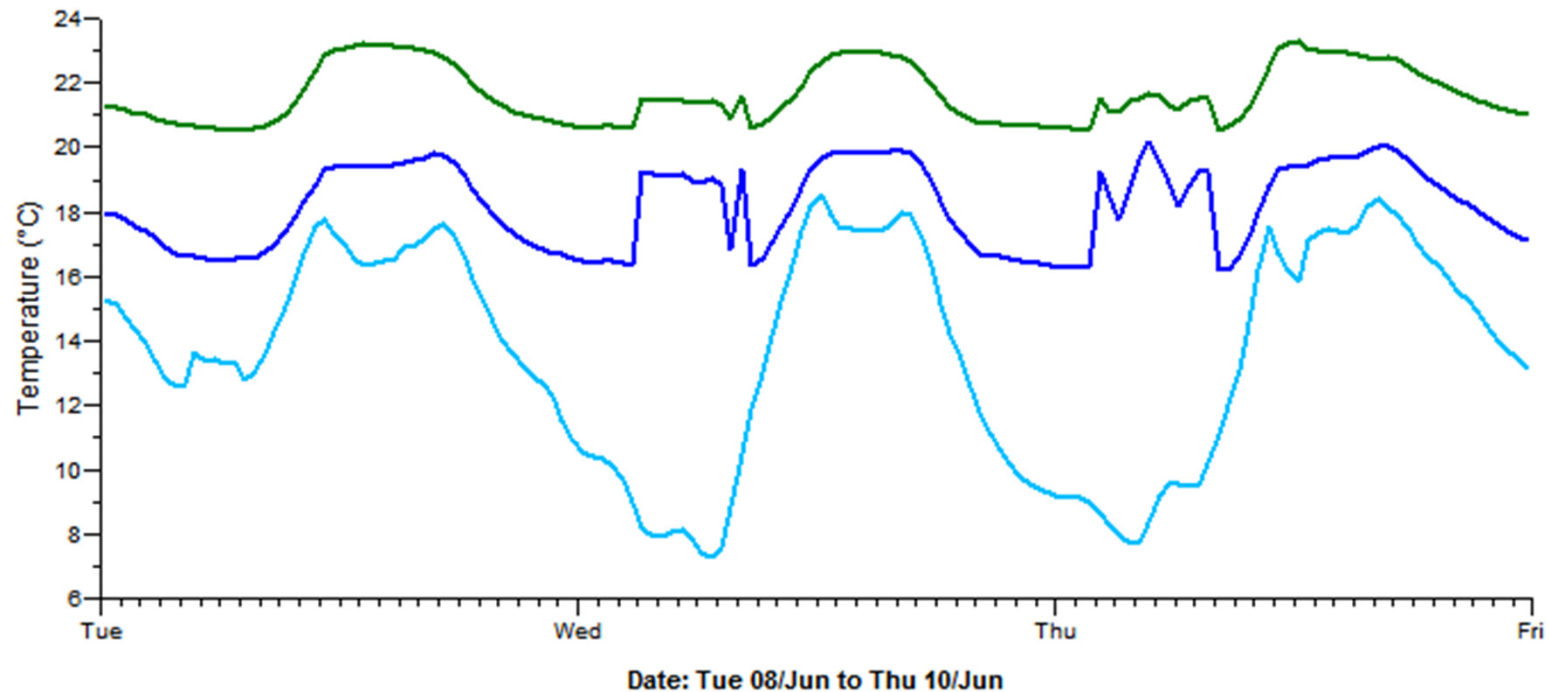


- Temperature in occupied zones (green, blue, and red lines) vs. outdoor temperature (light teal – Brisbane, AU, Mar 4-6).



## Passive downdraft cool towers

### Shoulder season performance of 2<sup>nd</sup>-floor occupied zone



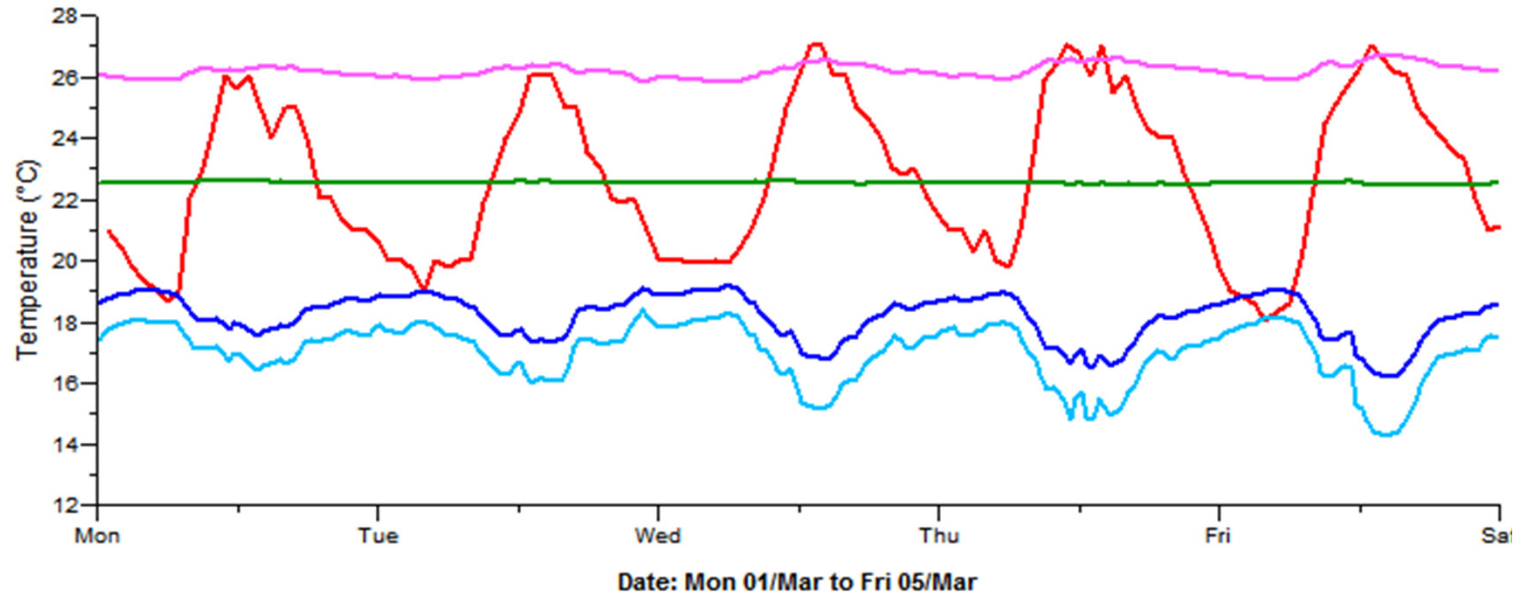
- Air temperature: 02 - Air supply plenum (cool twr - r12 - sys v7 - heat coil in f02 - june .aps)
- Air temperature: 02 - Occupied zone (cool twr - r12 - sys v7 - heat coil in f02 - june .aps)
- Air temperature: Cool Twr N - seg 2 (cool twr - r12 - sys v7 - heat coil in f02 - june .aps)

- Occupied zone temperature (green) is maintained by reducing flow from cool tower (light blue) to vent only and engaging floor plenum heating coil



## Passive downdraft cool towers

### Thermal stratification and temperatures on flow path: 1<sup>st</sup>-floor occupied zone

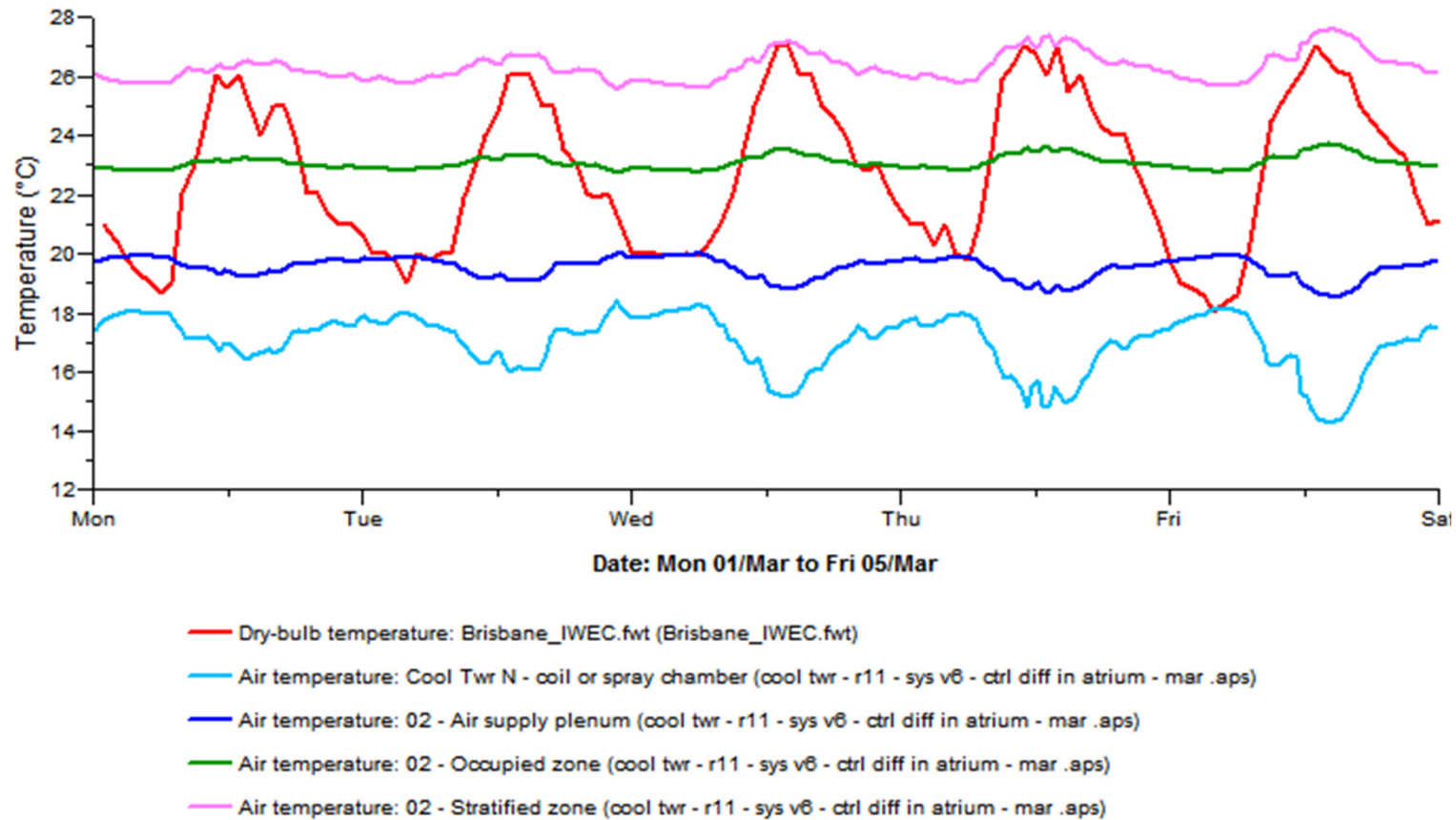


- Control of both coil LAT in towers and passive flow via dampers results in very tightly controlled space temperature and avoid excessive cooling.



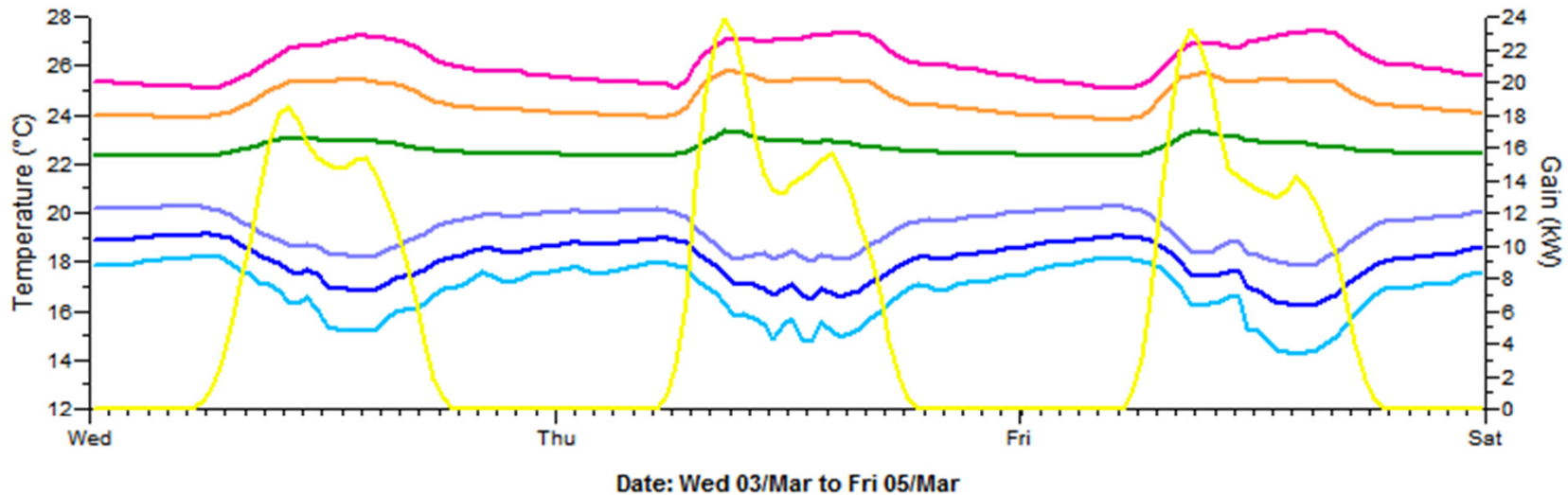
## Passive downdraft cool towers

### Thermal stratification and temperatures on flow path: 2<sup>nd</sup>-floor occupied zone



- Temperature in 2<sup>nd</sup>-floor occupied zone is slightly more variable as a result of heat transfer from RA below through floor deck into UFAD plenum.

## Thermal stratification and temperatures on flow path: atrium



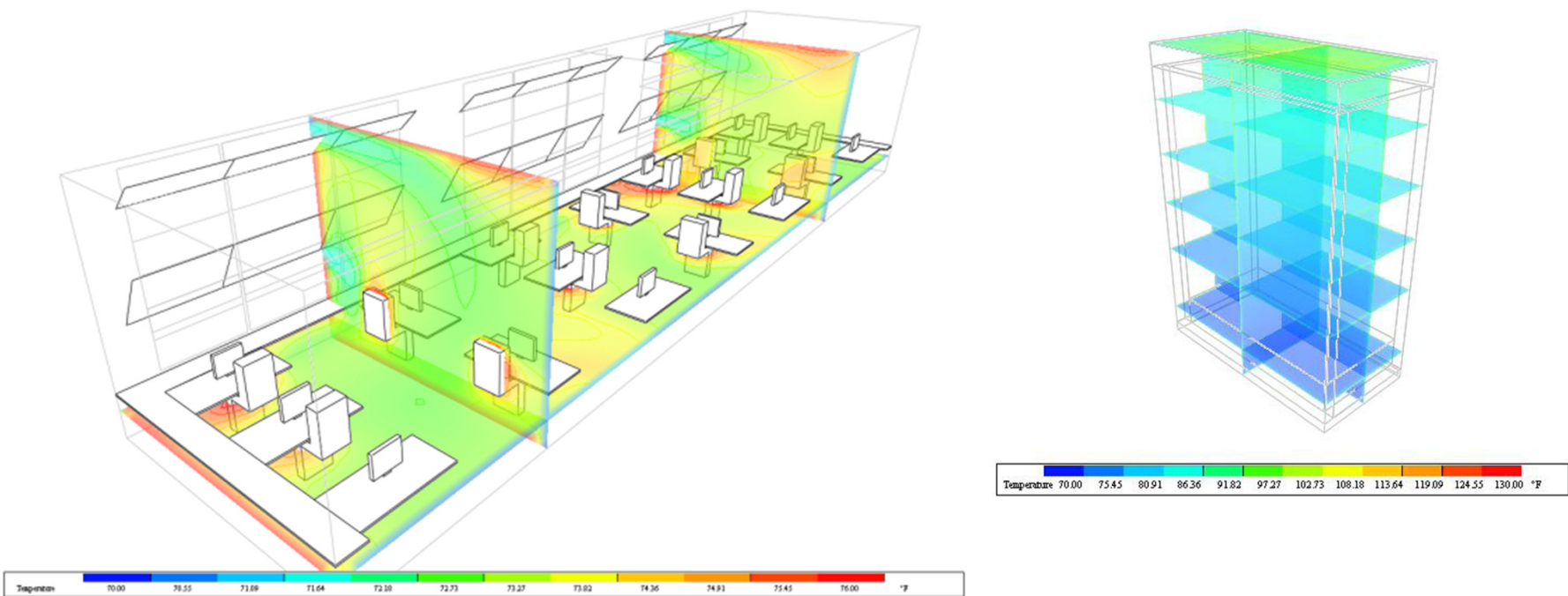
- Air temperature: Cool Twr N - coil or spray chamber (cool twr - r11 - sys v6 - ctrl diff in atrium - mar .aps)
- Air temperature: 01 - Air supply plenum (cool twr - r11 - sys v6 - ctrl diff in atrium - mar .aps)
- Air temperature: Atrium - Floor slab pedistal (cool twr - r11 - sys v6 - ctrl diff in atrium - mar .aps)
- Air temperature: Atrium - Occupied zone (cool twr - r11 - sys v6 - ctrl diff in atrium - mar .aps)
- Air temperature: Atrium - Stratified zone 1 (cool twr - r11 - sys v6 - ctrl diff in atrium - mar .aps)
- Air temperature: Atrium - Stratified zone 2 (upper) (cool twr - r11 - sys v6 - ctrl diff in atrium - mar .aps)
- Solar gain: Atrium - Occupied zone & Atrium - Stratified zone 2 (upper) & Atrium - Stratified zone 1 (cool twr - r11 - sys v6 - ctrl diff in atrium - mar .aps)

- Atrium occupied zone temperature is very consistent in spite of substantial solar gain as well as associated gain (1–2°C) in atrium floor plenum.

# Bulk airflow vs. CFD for air movement, buoyancy, and comfort

CFD can be very useful where bulk airflow modeling leaves off

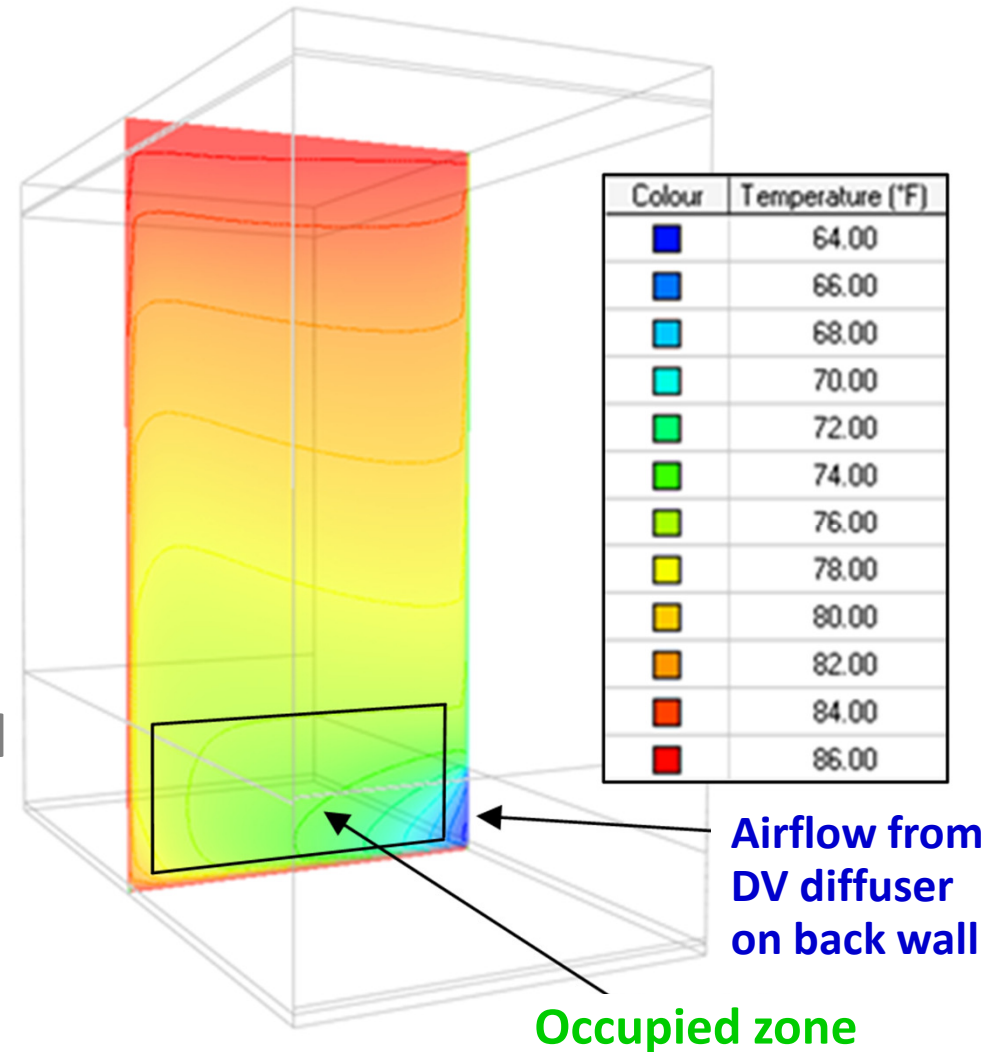
- Bulk-airflow model driven by temperature difference for adjacent *fully mixed* zones.
  - No wind-driven or stack-effect flows *within* a zone (only at openings between).
  - No thermal plumes adding to overhead “pool” of hot air.
- Use CFD to predict air movement and associated local thermal comfort conditions.
  - Where temp gradients are significant, use zonal method for energy model.
  - Use CFD to calibrate or tune the zonal bulk-airflow model





## Atrium analysis example: CFD model

- Single volume (no zonal subdivisions)
- Initial boundary conditions for each test case taken from selected time step in zonal thermal and HVAC model
- Initial DV airflow and temperature at large side-wall diffuser set to the same value used in the zonal thermal and HVAC model



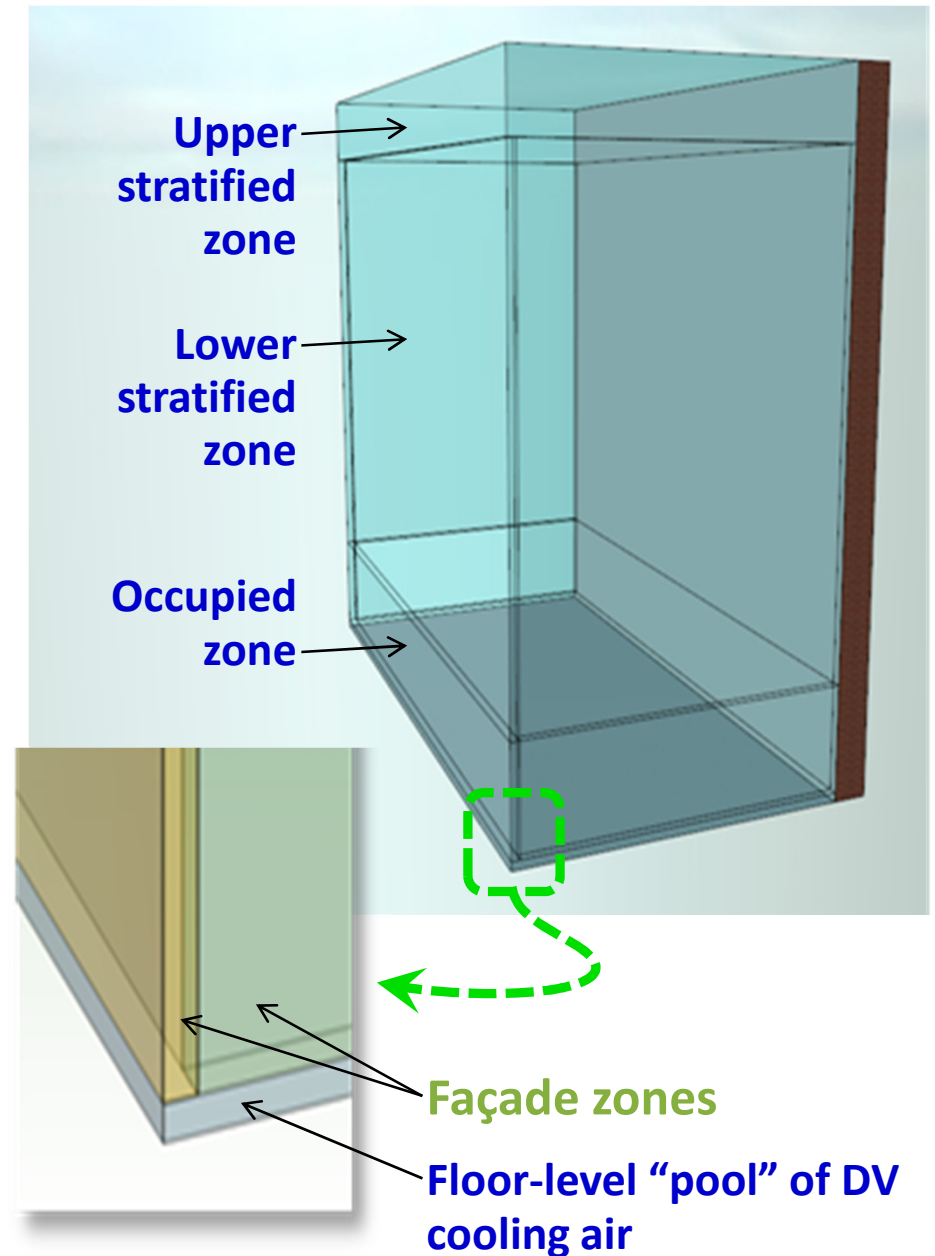
- Temperature at center of occupied zone was basis for comparison of airflow requirements at a given supply air temperature.





## Zonal model of atrium for MacroFlo and ApacheHVAC

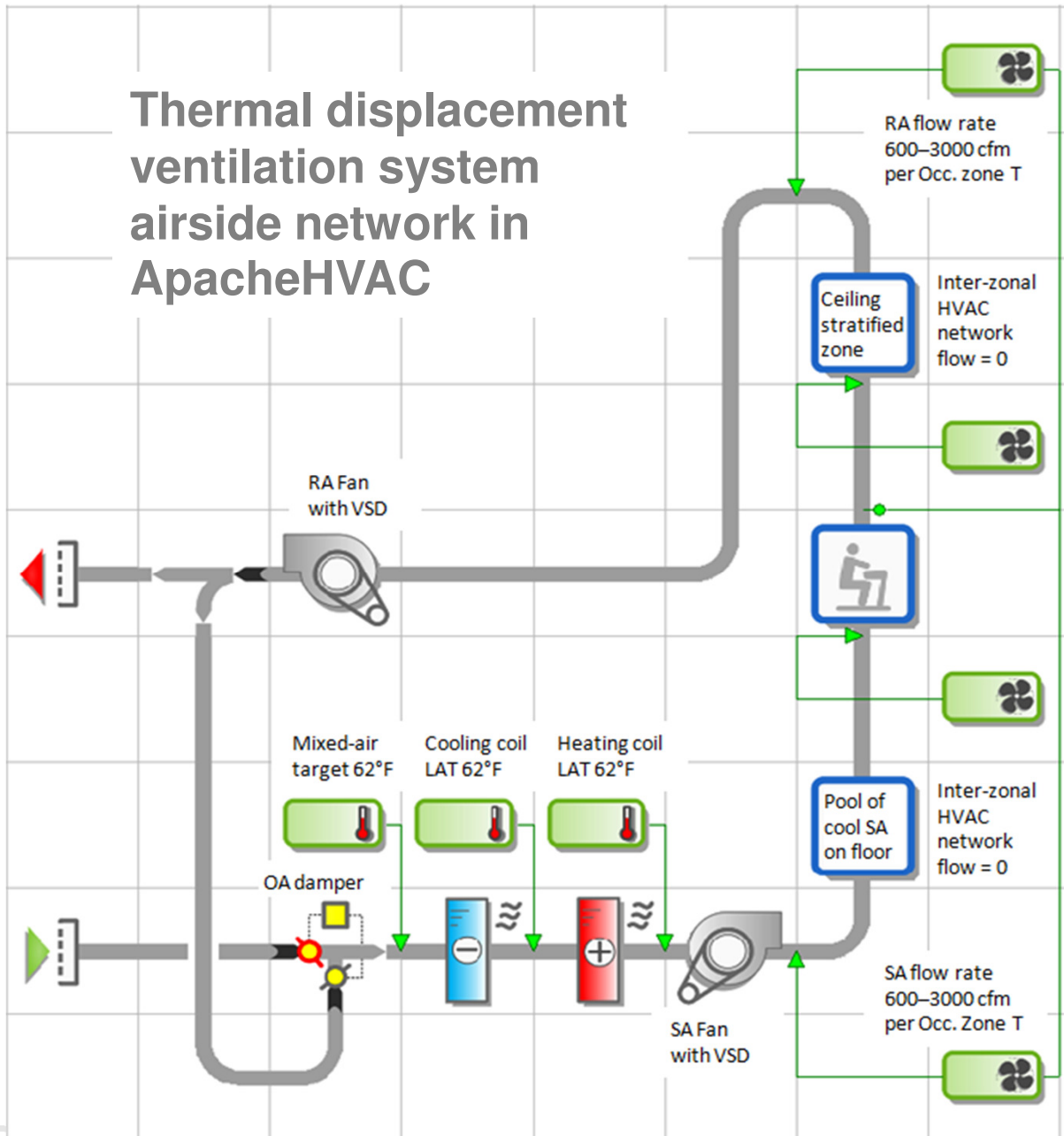
- Subdivision of atrium into 10 zones:
  - 6-in deep “pool” of cooling air (SA introduced here)
  - 7.5-ft Occupied zone above the cooling air pool
  - 28-ft Lower stratified zone
  - 4-ft Upper stratified zone against the ceiling
  - 6-in deep Façade zones for each orientation
    - Matching height of occupied and lower stratified zones
    - Concentrated zone of convective heating at glass surfaces



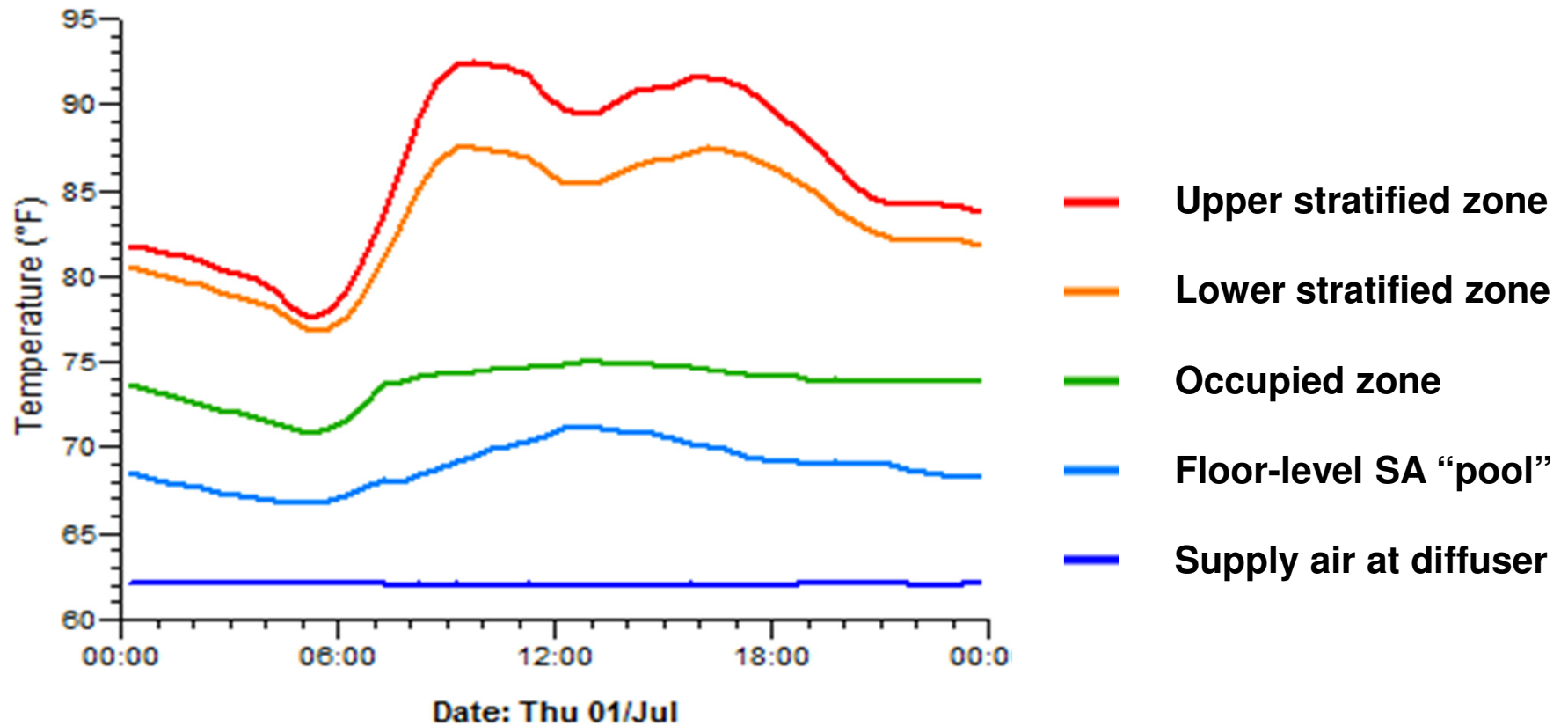


# Atrium HVAC system model

## Thermal displacement ventilation system airside network in ApacheHVAC



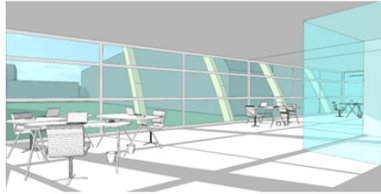
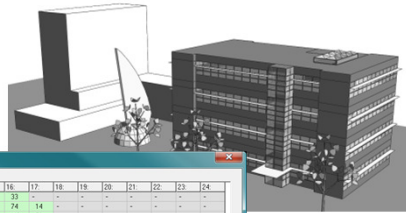
 **Atrium zone temperatures: Zonal method with MacroFlo + ApHVAC**



Zone temperatures for the zonal modeling method: 10-zone model with bulk-airflow network.



# IES <Virtual Environment> Integrated building performance analysis



Summary Information	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	-	-	-	-	-	-	-	45	93	129	151	157	148	127	83	33	-	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	-	17	77	119	146	160	199	189	164	125	74	14	-	-	-	-	-	-
Mar	-	-	-	-	-	1	86	127	178	216	239	247	236	209	167	113	62	-	-	-	-	-	-	-
Apr	-	-	-	-	-	59	124	182	231	268	288	292	279	250	206	152	90	25	-	-	-	-	-	-
May	-	-	-	-	-	36	100	160	216	262	297	315	319	305	276	233	181	120	58	-	-	-	-	-
Jun	-	-	-	-	-	52	112	172	228	272	305	325	325	317	289	249	199	140	80	20	-	-	-	-
Jul	-	-	-	-	-	39	101	161	216	264	299	321	326	314	288	249	199	140	80	18	-	-	-	-
Aug	-	-	-	-	-	9	74	136	195	244	288	302	307	286	258	227	174	113	58	-	-	-	-	-
Sep	-	-	-	-	-	38	103	161	210	246	265	269	254	223	178	123	59	-	-	-	-	-	-	-
Oct	-	-	-	-	-	2	84	122	167	209	217	216	200	167	120	84	1	-	-	-	-	-	-	-
Nov	-	-	-	-	-	23	78	122	153	168	166	152	128	78	21	-	-	-	-	-	-	-	-	-
Dec	-	-	-	-	-	49	92	125	143	146	132	104	62	18	-	-	-	-	-	-	-	-	-	-

**Chilled water loop**

Reference: Electric Water-Cooled Chiller with Water-Source HX pre-cool and Fluid Cooler with IWSE mode

Sizing status: Design calculation successful.

Chilled water loop | Pre-cooling | Chiller set | Heat rejection

**General**

Design outdoor dry-bulb temperature: 50.00 °F

Design outdoor wet-bulb temperature: 45.00 °F

Location of pre-cooling loop: Secondary return

Pre-cooling capacity

Autosize [% of CHWL capacity]: 25.00      Capacity: 744.64 kbtu/h A

Heat rejection devices

Water source heat exchanger

Ambient device: Cooling tower with heat exchanger

Water source heat exchanger: Cooling tower with heat exchanger | Fluid cooler

Cooling capacity

Autosize [% of PC capacity]: 100.00      Capacity: 744.64 kbtu/h A

Source water

Source water temperature: Constant 60.00 °F

Source water temperature profile: None

Source water specific pump power: 19.00 W/gpm

**Design parameters**

Load-side flow rate: 496.25 gpm

Load-side delta T: 3.00 °F

Load-side leaving temperature: 62.00 °F

Source-side entering temperature: 60.00 °F

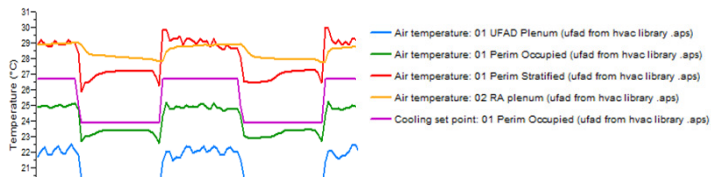
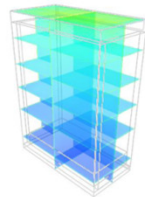
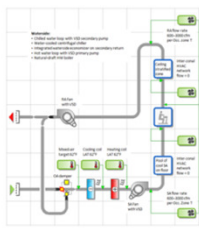
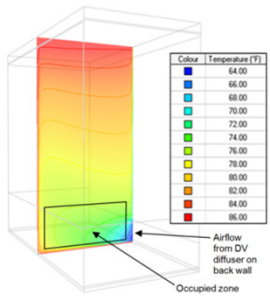
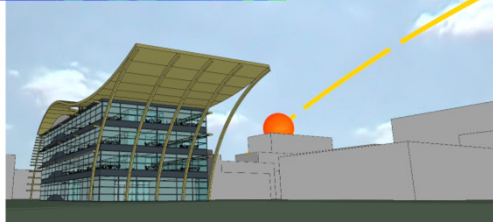
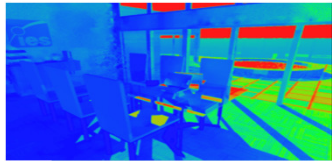
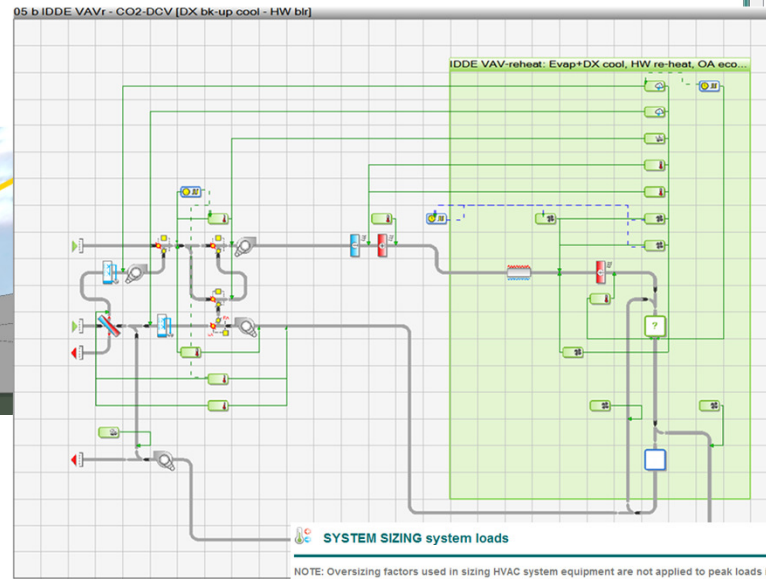
Approach: 2.00 °F

Heat exchanger effectiveness: 0.80

Source-side delta T: 4.00 °F

Source-side flow rate: 372.56 gpm

OK    Cancel



System ID	System Name				Area Served (m²)
PR05_040	b IDDE VAVr - CO2-DCV (DX bk-up cool - HW blr)				333.71
<b>Coil Sizes</b>	AHU Cooling Coil	AHU Cooling Coil	AHU Cooling Coil	AHU Heating Coil	
	Sensible Load (kW)	Latent Load (kW)	Total Load (kW)	Total Load (kW)	
Peak value	3.05	-0.00	3.05	9.63	
Time of Peak	7/15 15:30	7/15 15:30	7/15 15:30	Sized during heating	
<b>Fan Sizes</b>	AHU Supply Fan	AHU Return Fan	Optional Exhaust Fan	Min Vent Airflow	
	Flow (l/s)	Flow (l/s)	Flow (l/s)	Flow (l/s)	
Peak Value	1367.51	1095.67	271.84	271.84	
Time of Peak	7/15 15:30	7/15 15:30	Sized during heating		
<b>Engineering Checks</b>	Cooling Checks		Heating Checks		
	l/s/m²	W/m²	% OA	l/s/m²	% OA
Peak Value	4.10	9.14	19.88	1.91	71.95
Time of Peak	7/15 15:30	Calculated at time of Peak Cooling Coil Load		Sized during heating	Calculated at time of Peak Heating Coil Load
<b>Rooms Served by System</b>	Components		Airflows		
	Cooling Coil Sensible Load (kW)	Cooling Coil Latent Load (kW)	Cooling Coil Total Load (kW)	Heating Coil Total Load (kW)	Zone recirc Fan Flow (l/s)
01 - Interior	-	-	-	1.70	303.72
01 East	-	-	-	3.57	356.91
01 North	-	-	-	2.20	200.06
01 South	-	-	-	3.55	398.76
01 West	-	-	-	348.19	104.46
01_Services	-	-	-	0.00	271.84
					Minimum Flow (l/s)
					Maximum Flow (l/s)
					Exhaust Flow (l/s)
					OA Flow (l/s)
					55.06
					31.71
					23.79
					38.64
					31.71
					0.00

