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

INTEGRATED ENVIRONMENTAL SOLUTIONS

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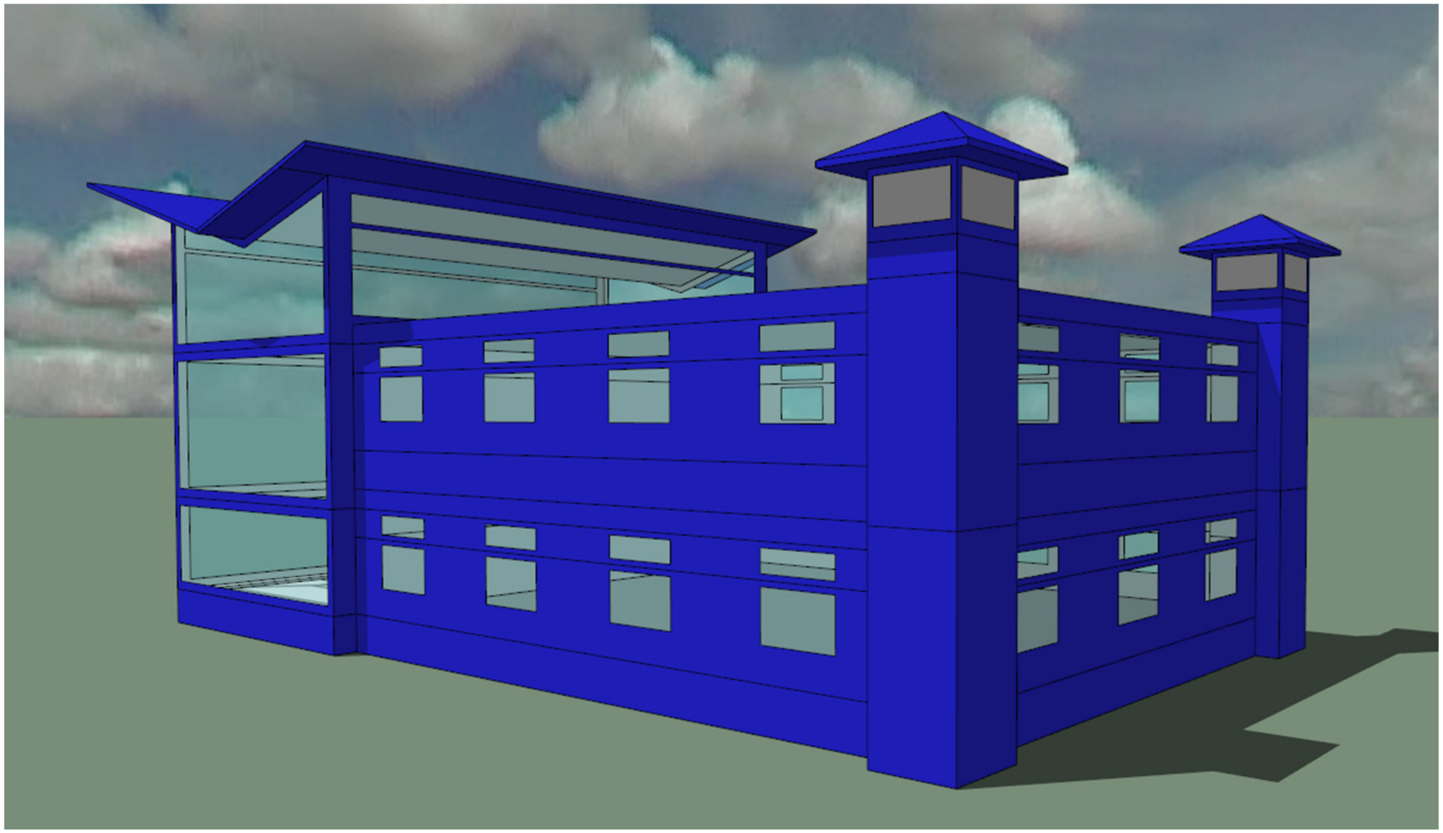
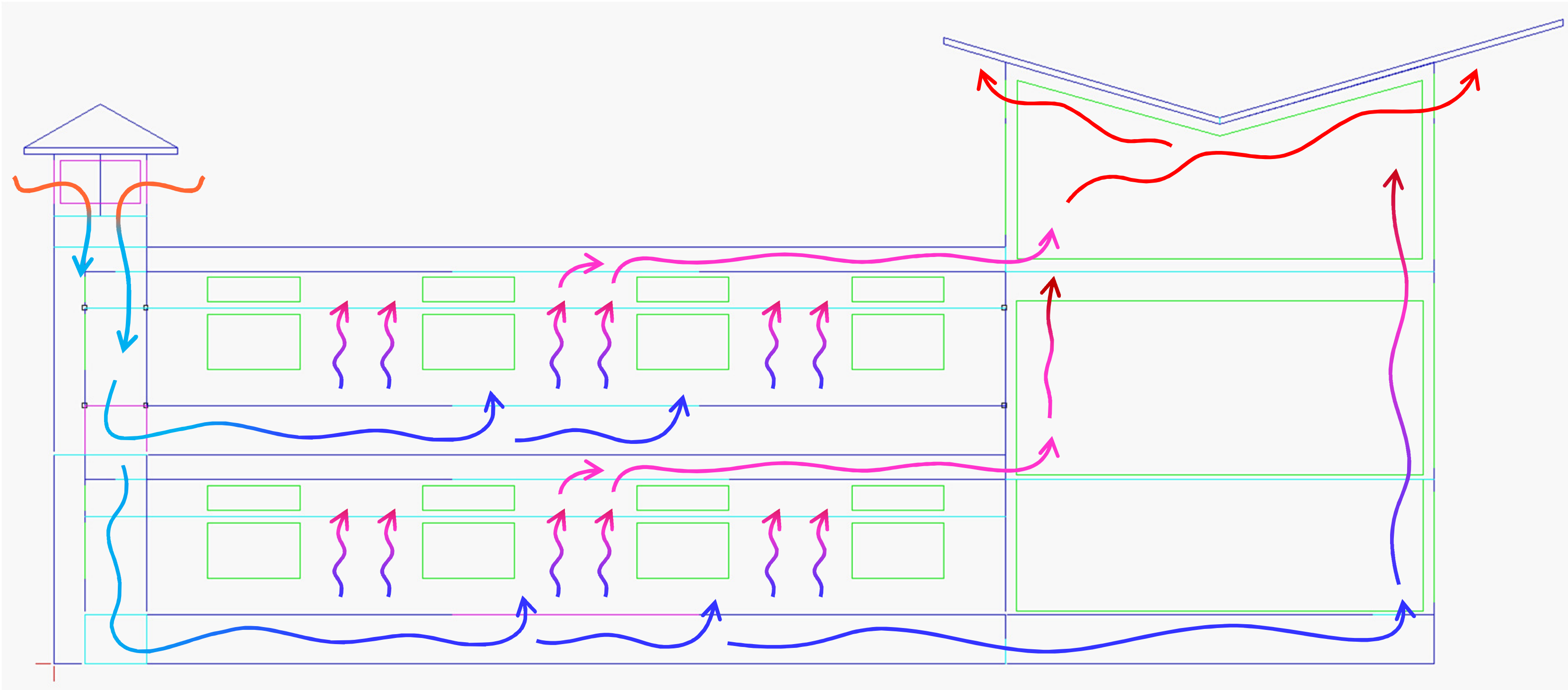
Passive downdraft cool towers + thermally stratified zones, atrium

- 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



Passive downdraft cool towers

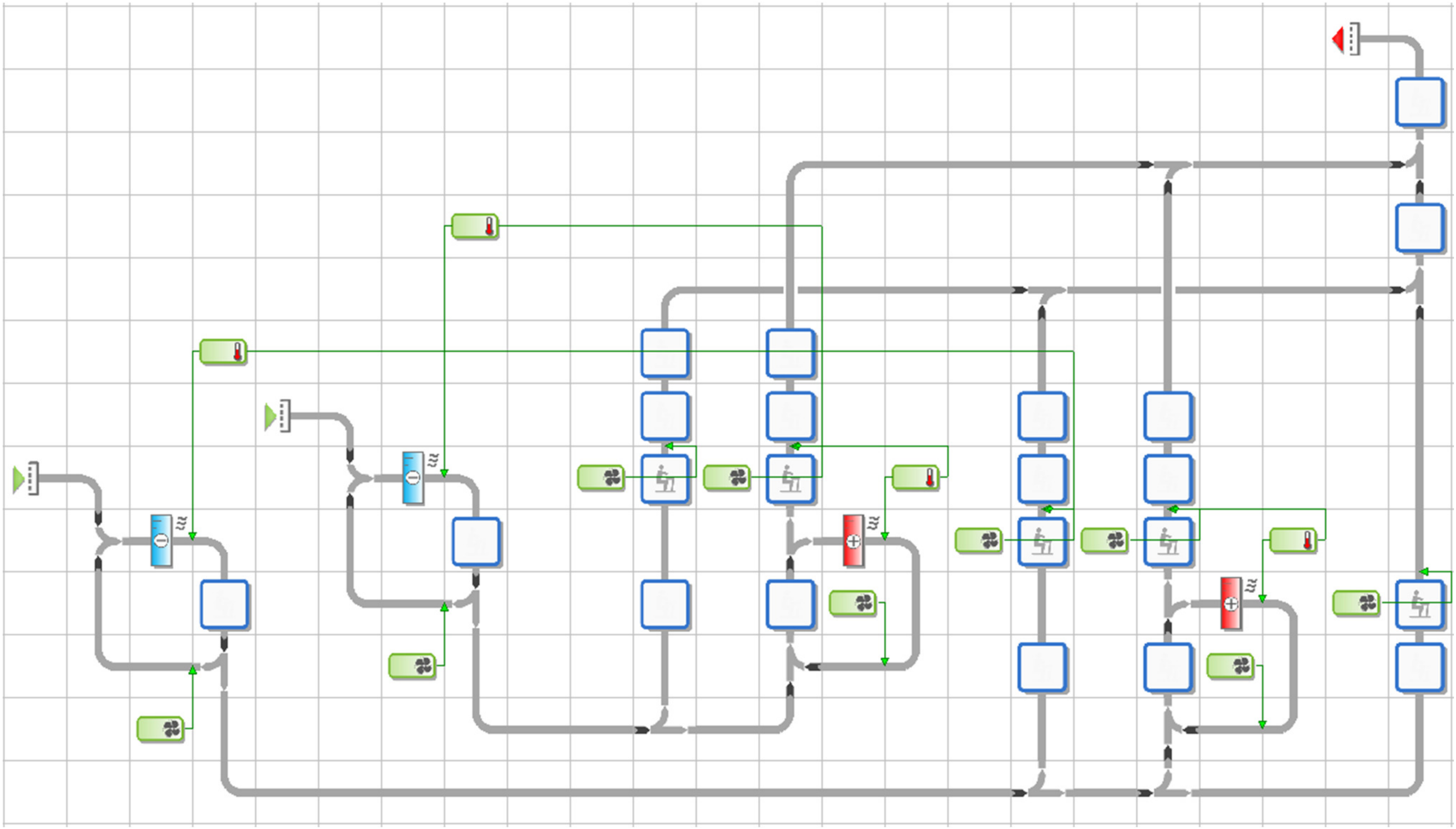


- Two downdraft towers: both have controllable inlets; one has wind baffles.
- UFAD supply air plenums
  - 1st floor provides example of controlled vent/cooling diffusers; heat by room units.
  - 2nd floor uses controlled inlets from towers to plenum; heat by coils in plenum.
- Occupied & stratified 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

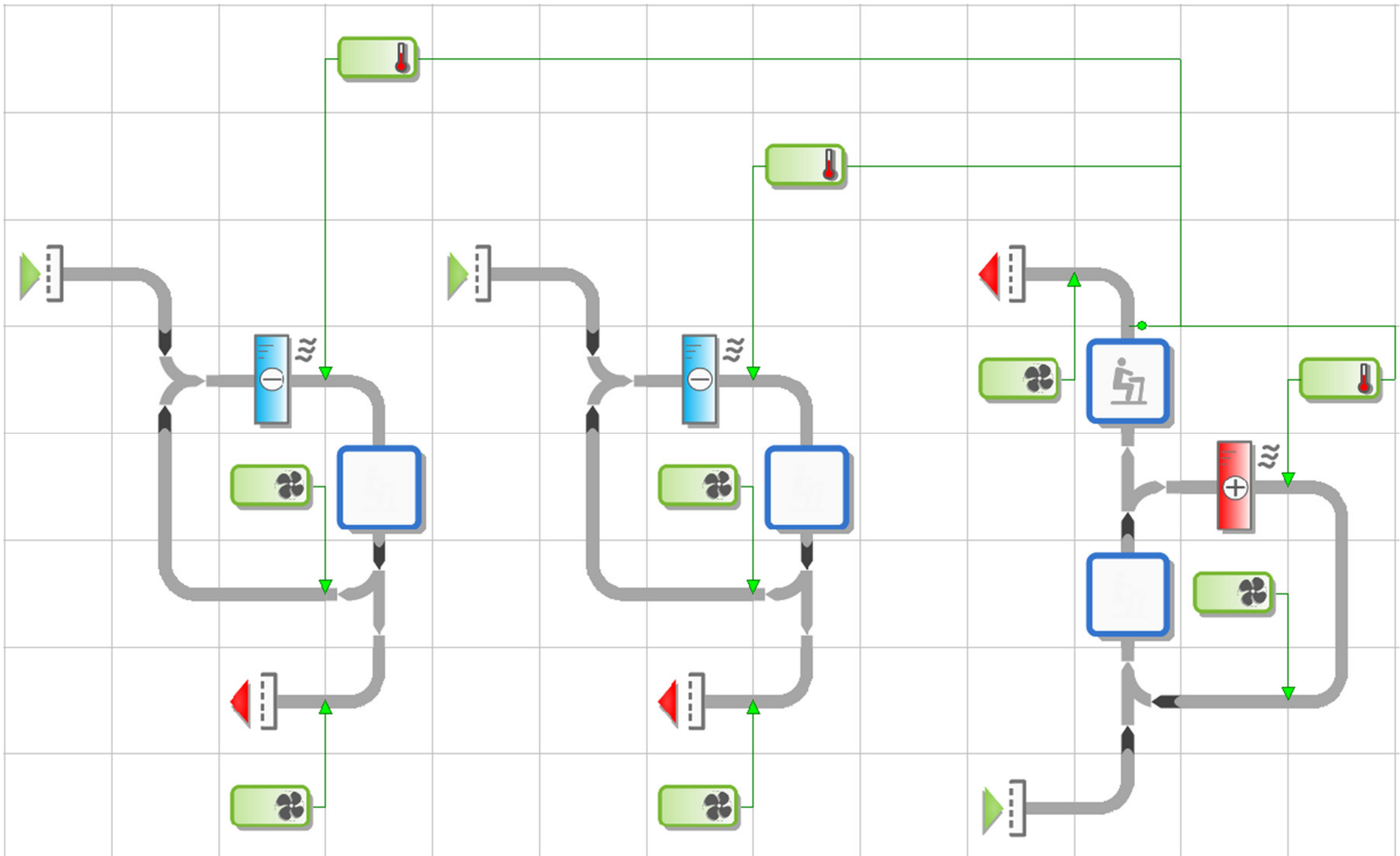
Complete network with all zones and nodes included.

- Facilitated adding damper sets and heating coils where needed.



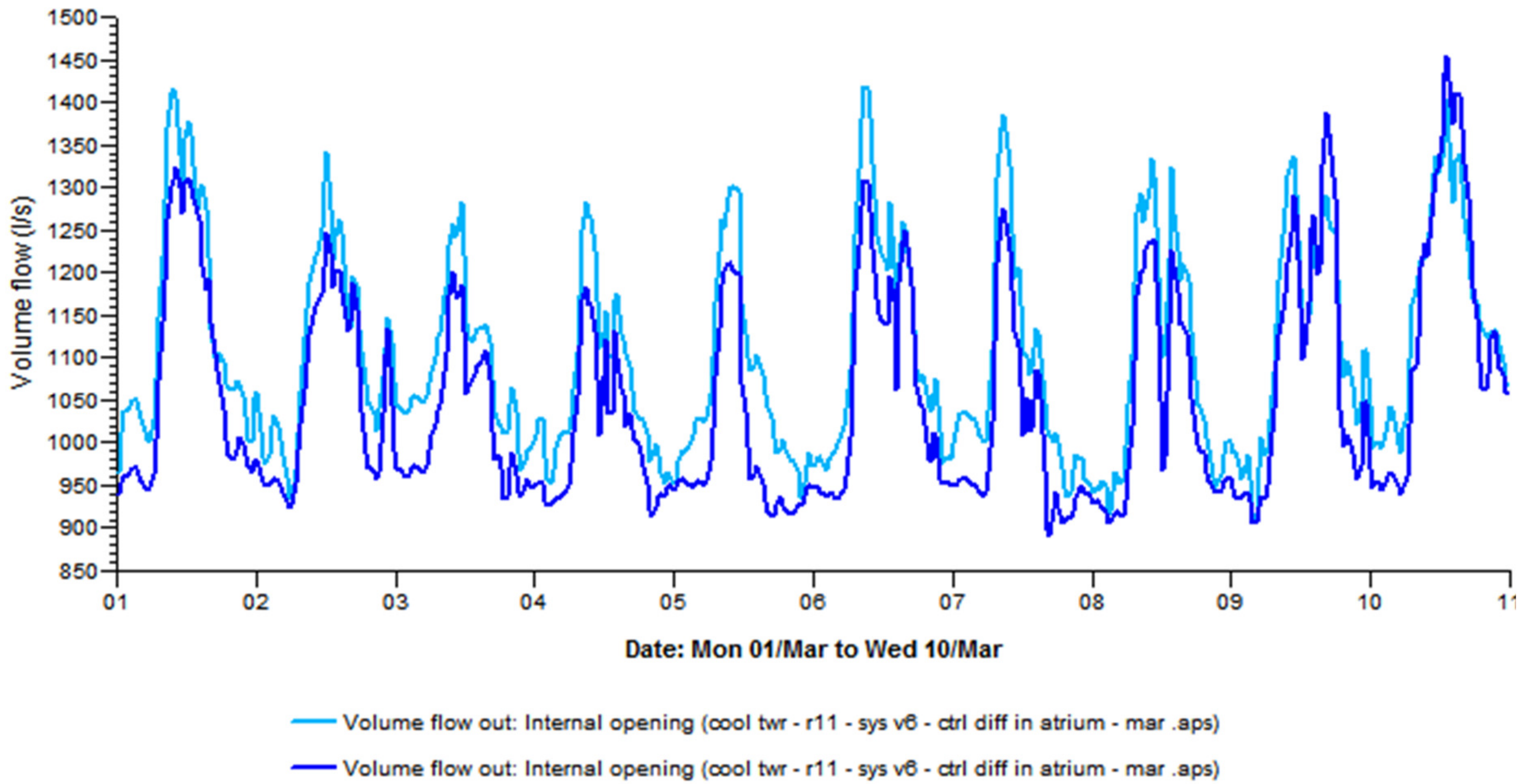
Passive downdraft cool towers

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



Passive downdraft cool towers

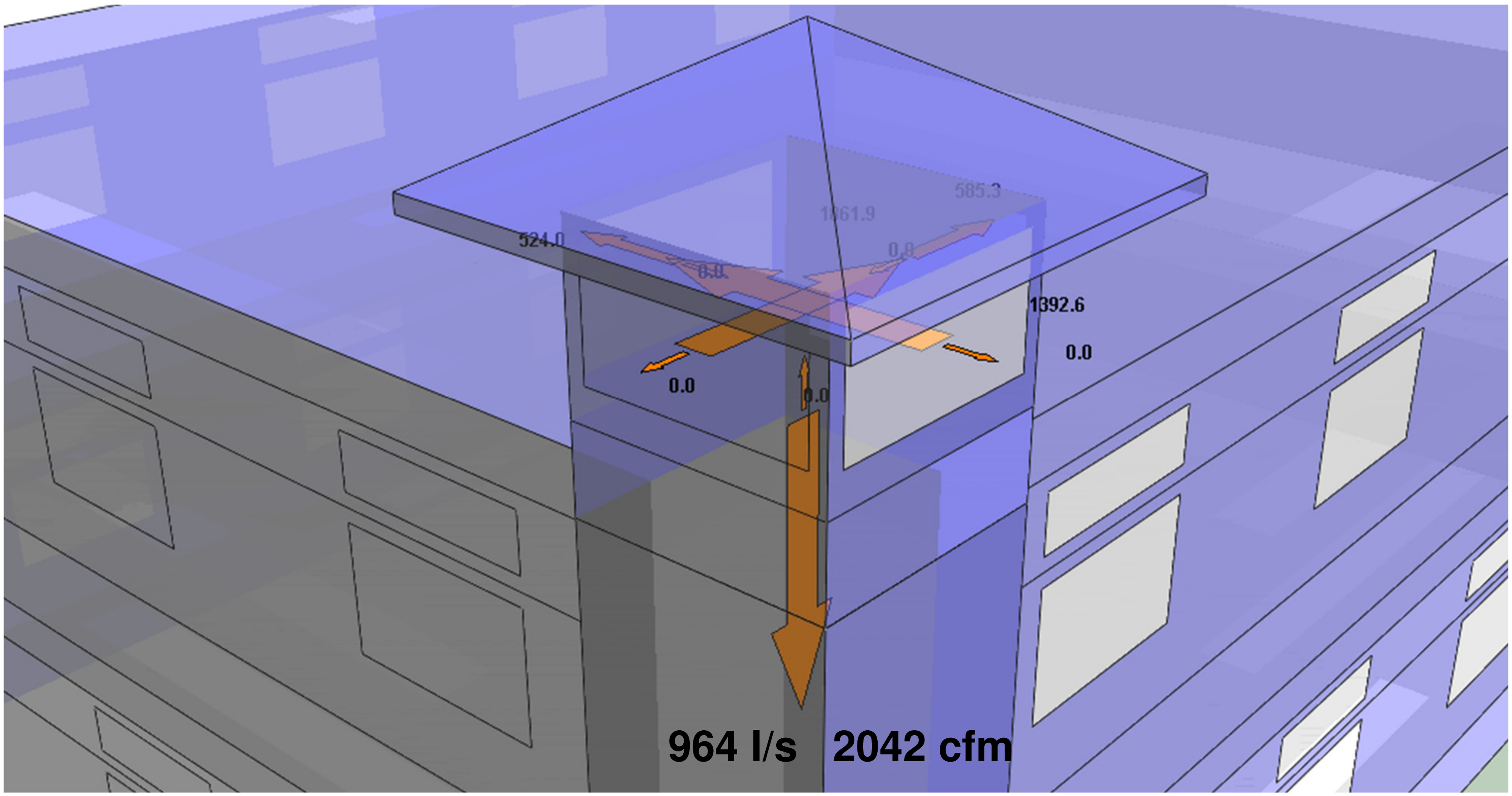
Confirming downdraft flow between cells in cool towers



- 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

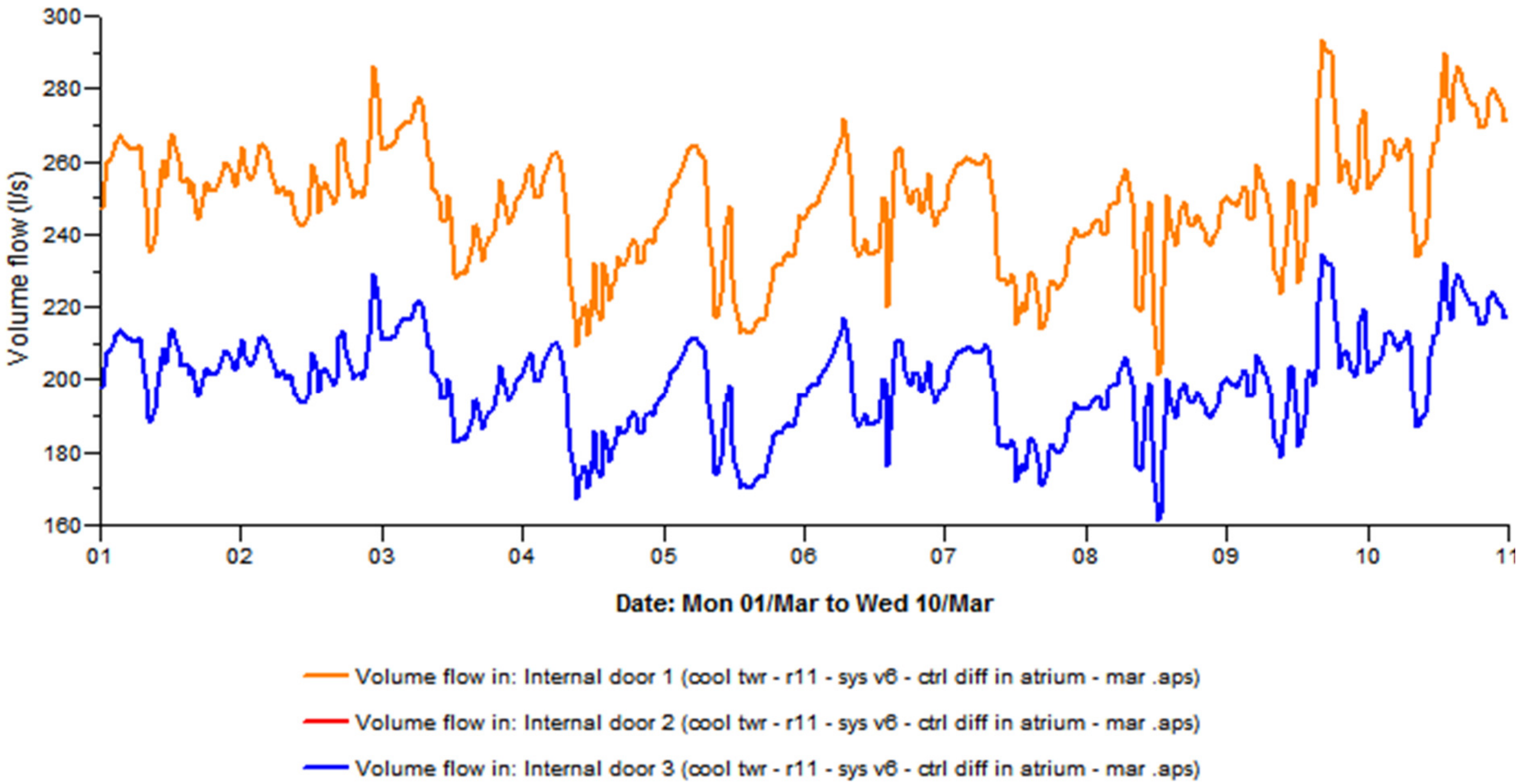
Confirming flow into the towers and the majority of the flow down from there



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

Passive downdraft cool towers

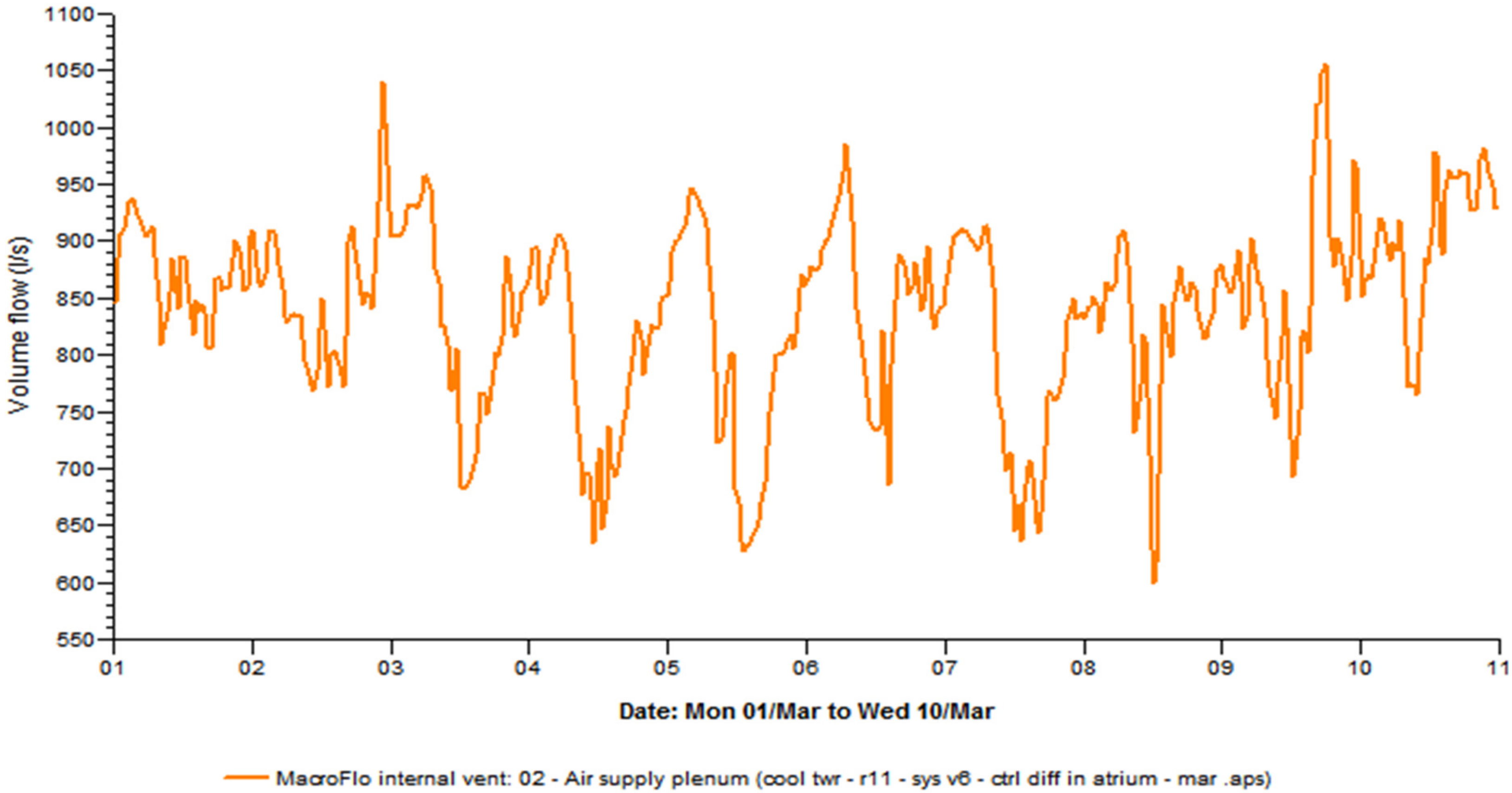
Confirming flow at controlled floor diffusers



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

Passive downdraft cool towers

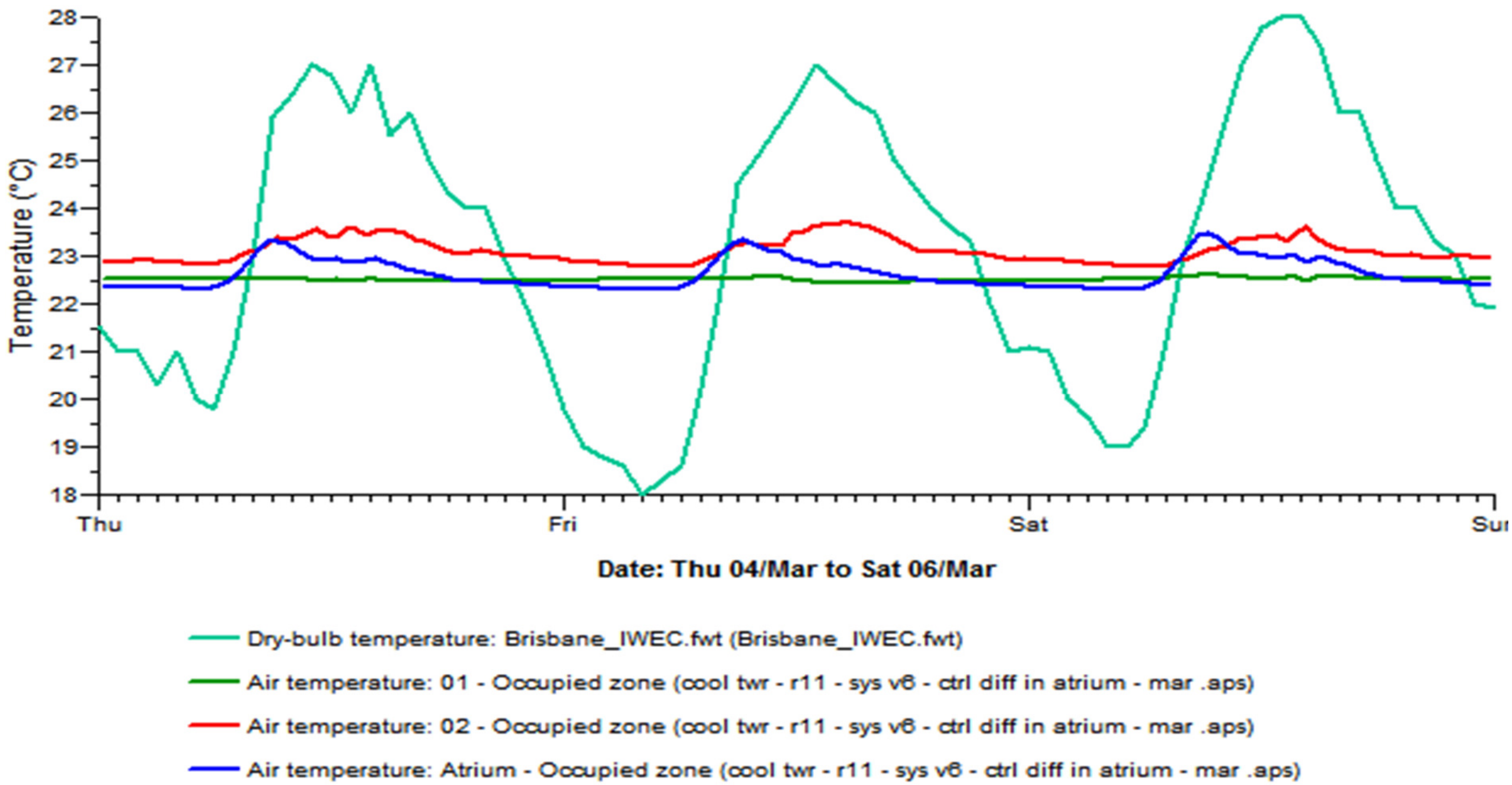
Confirming flow through inlet dampers on 2nd-floor UFAD plenum



- Flow into the 2nd-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

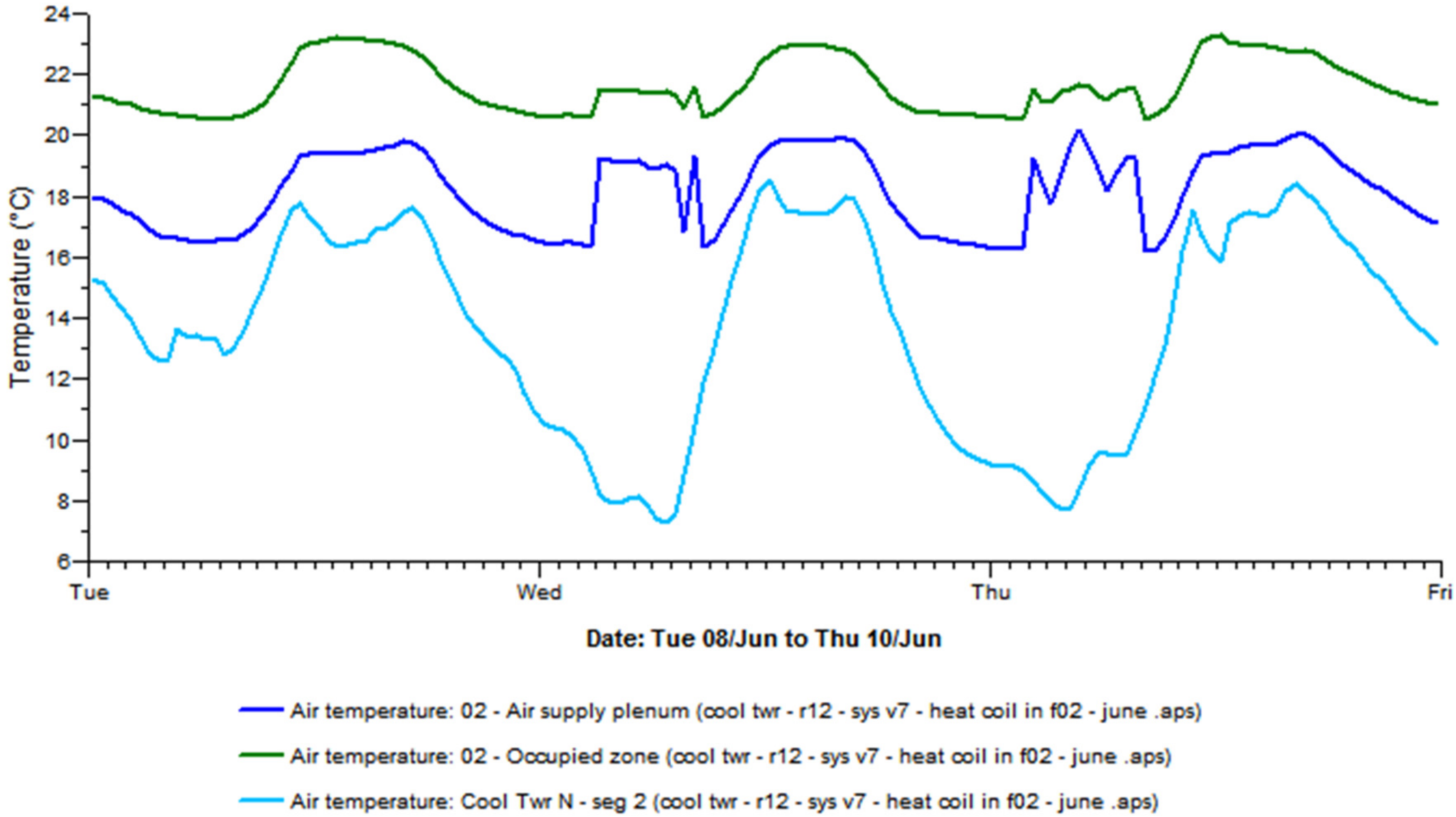
Maintaining cooling setpoint (23°C +/- 1°C) in summer



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

Passive downdraft cool towers

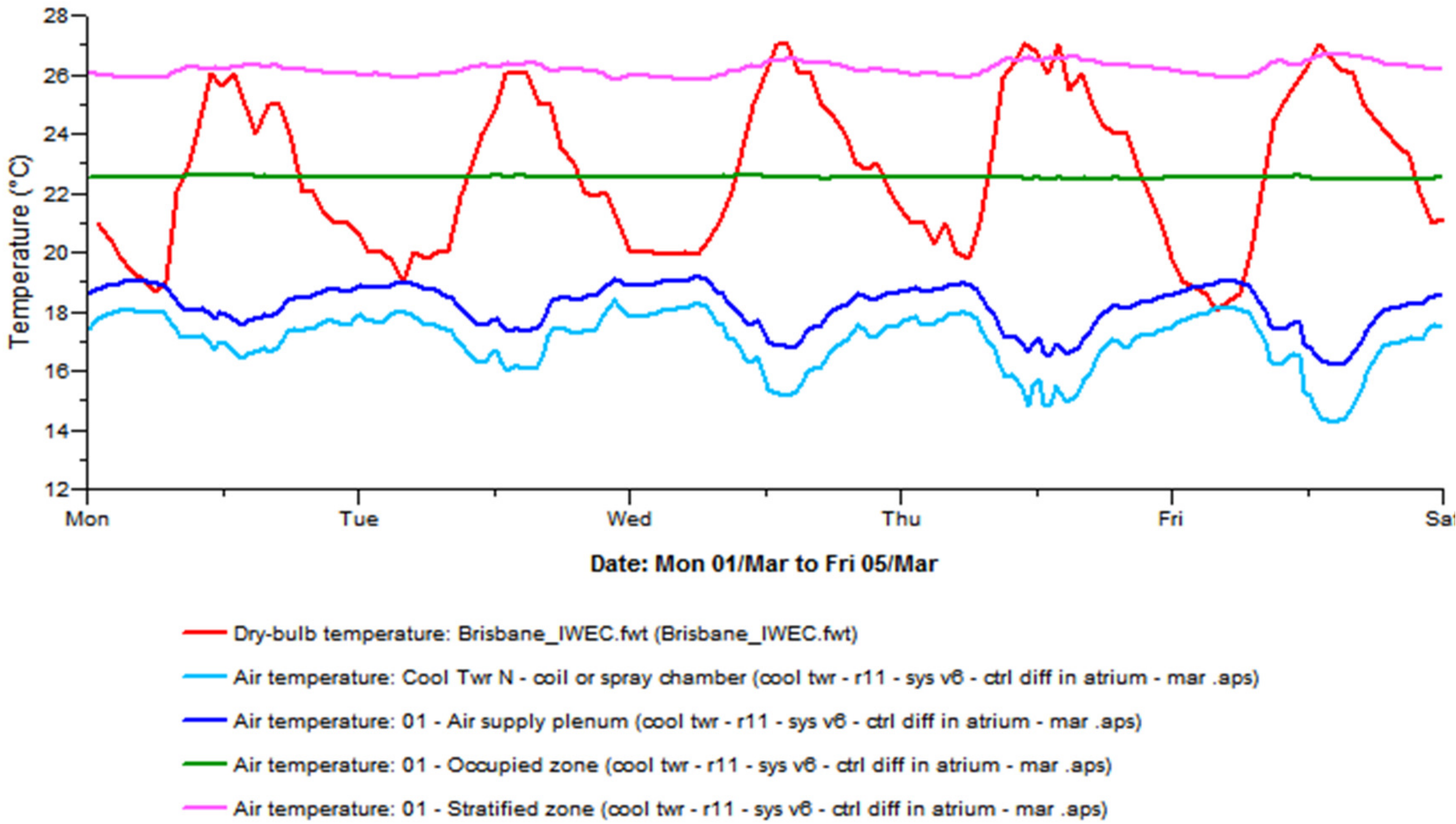
Shoulder season performance of 2nd-floor occupied zone



- 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

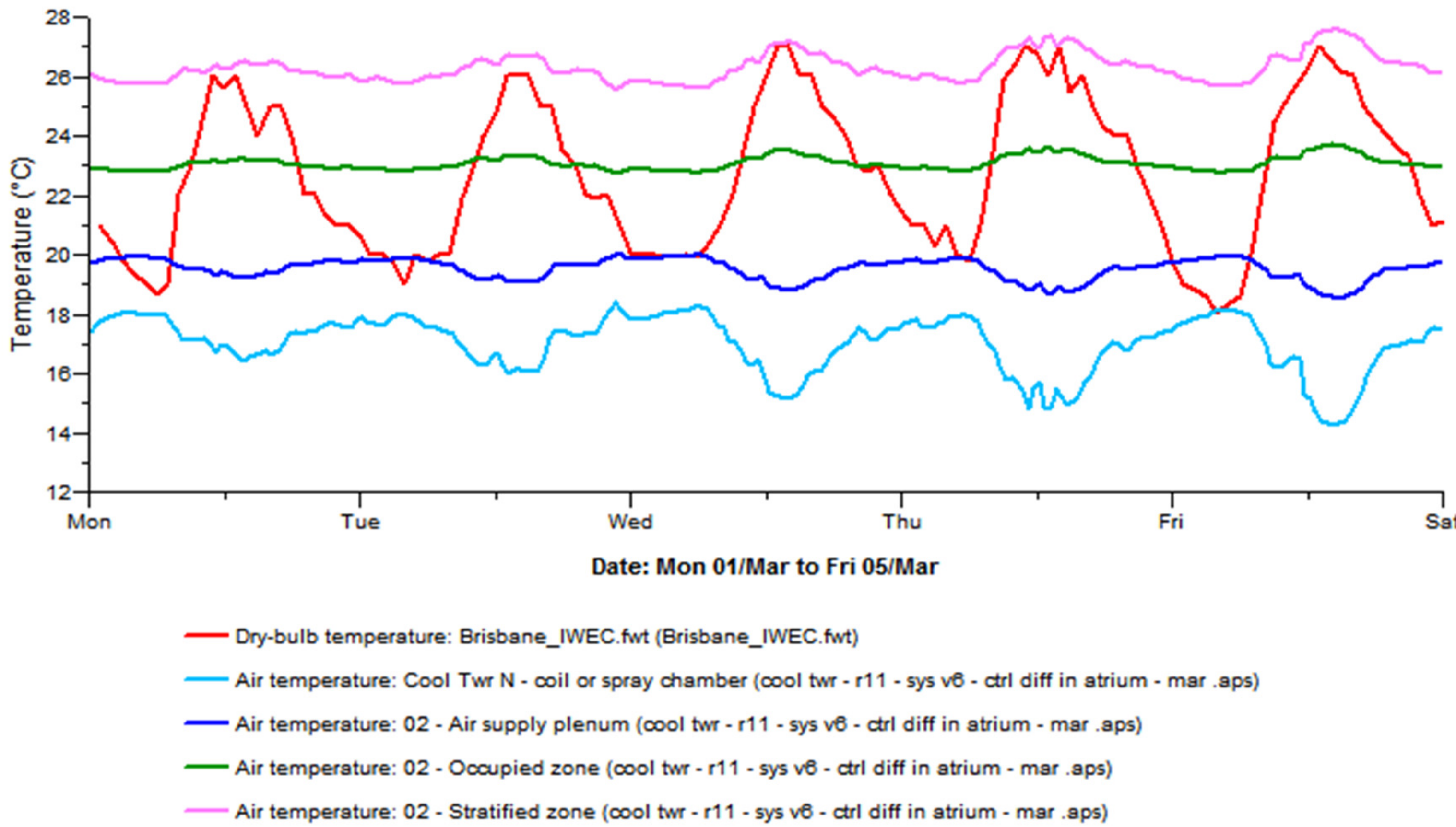
Thermal stratification and temperatures on flow path: 1st-floor occupied zone



- 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

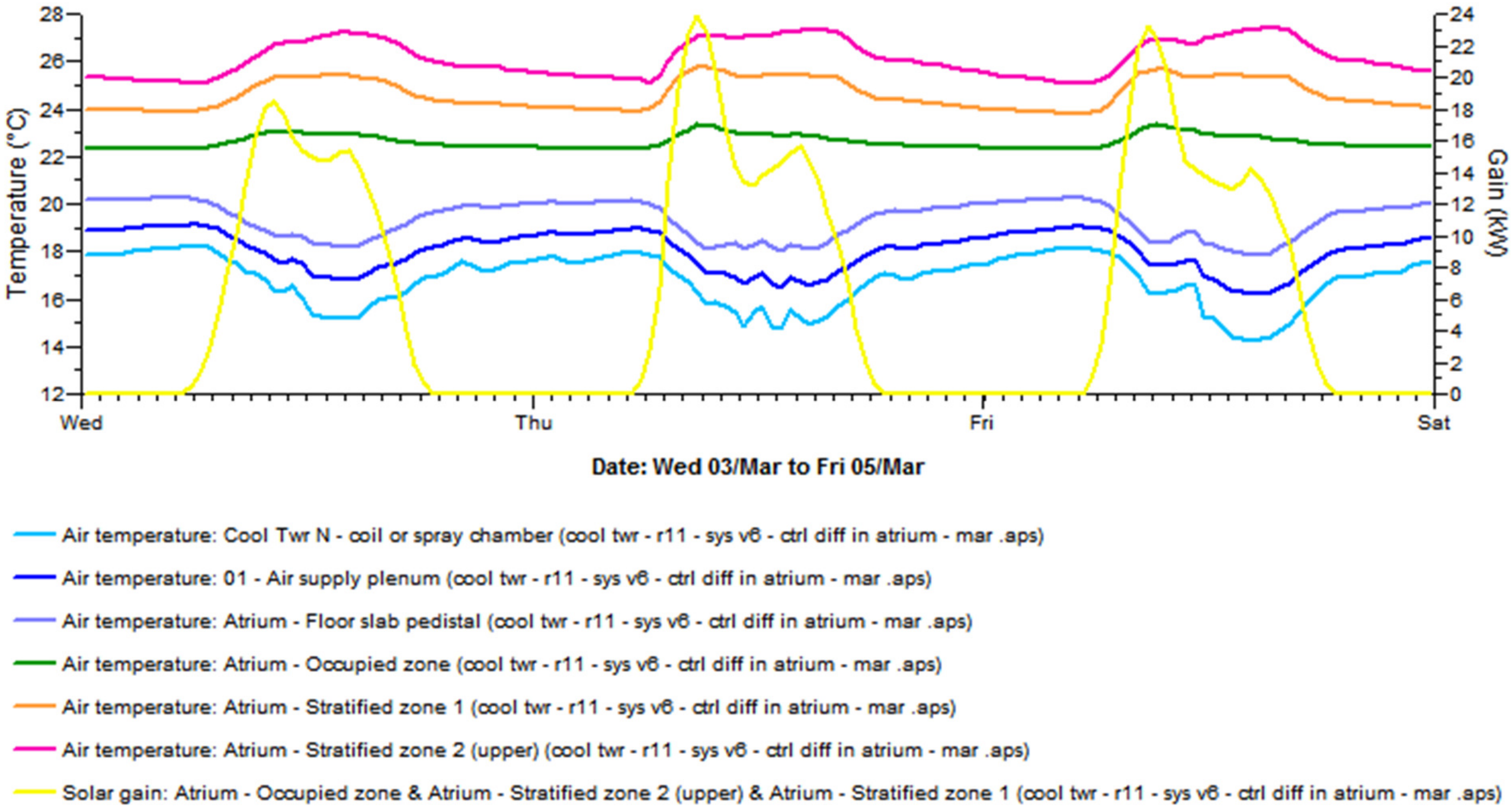
Thermal stratification and temperatures on flow path: 2nd-floor occupied zone



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

Passive downdraft cool towers

Thermal stratification and temperatures on flow path: atrium

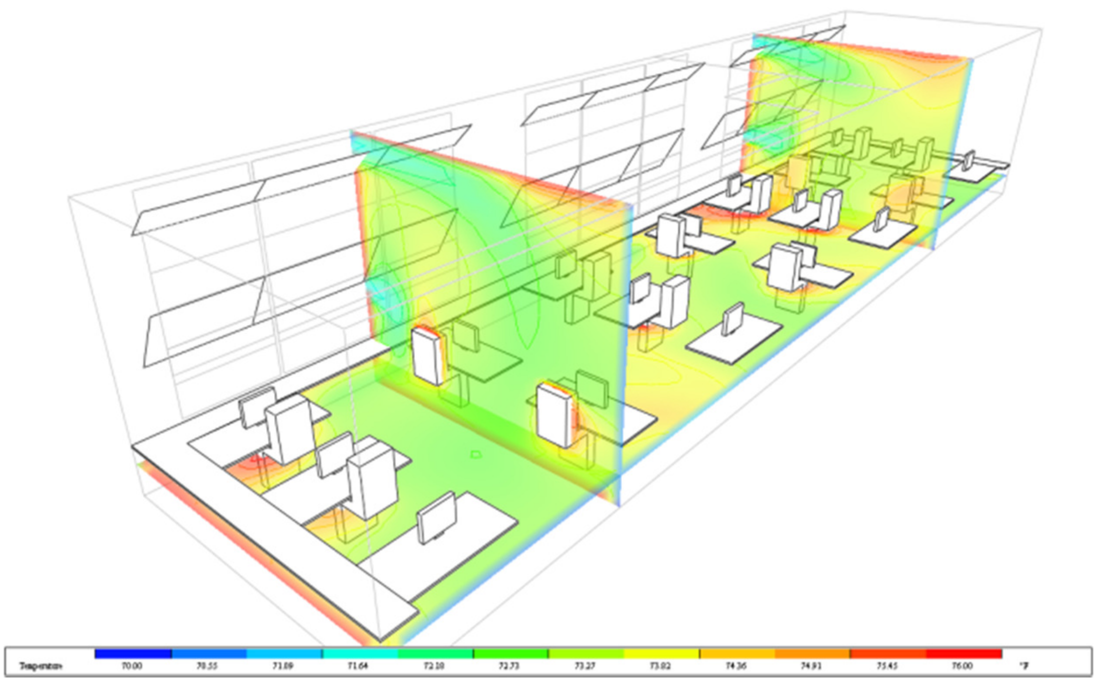


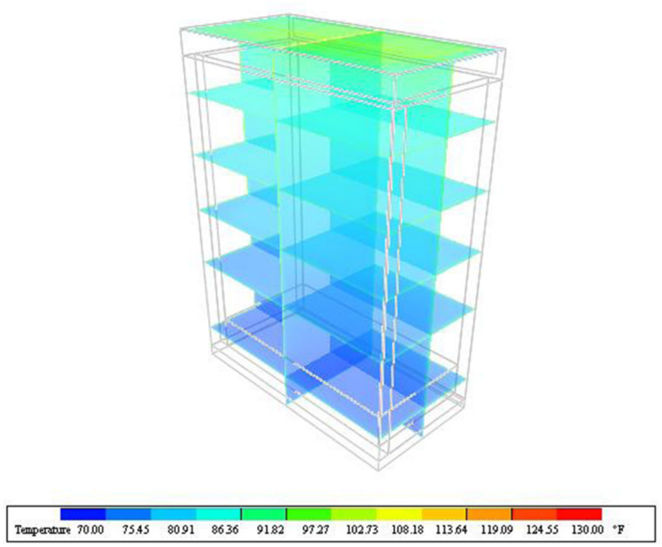
- Atrium occupied zone temperature is very consistent in spite of substantial solar gain as well as associated gain (1–2°C) in atrium floor plenum.

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



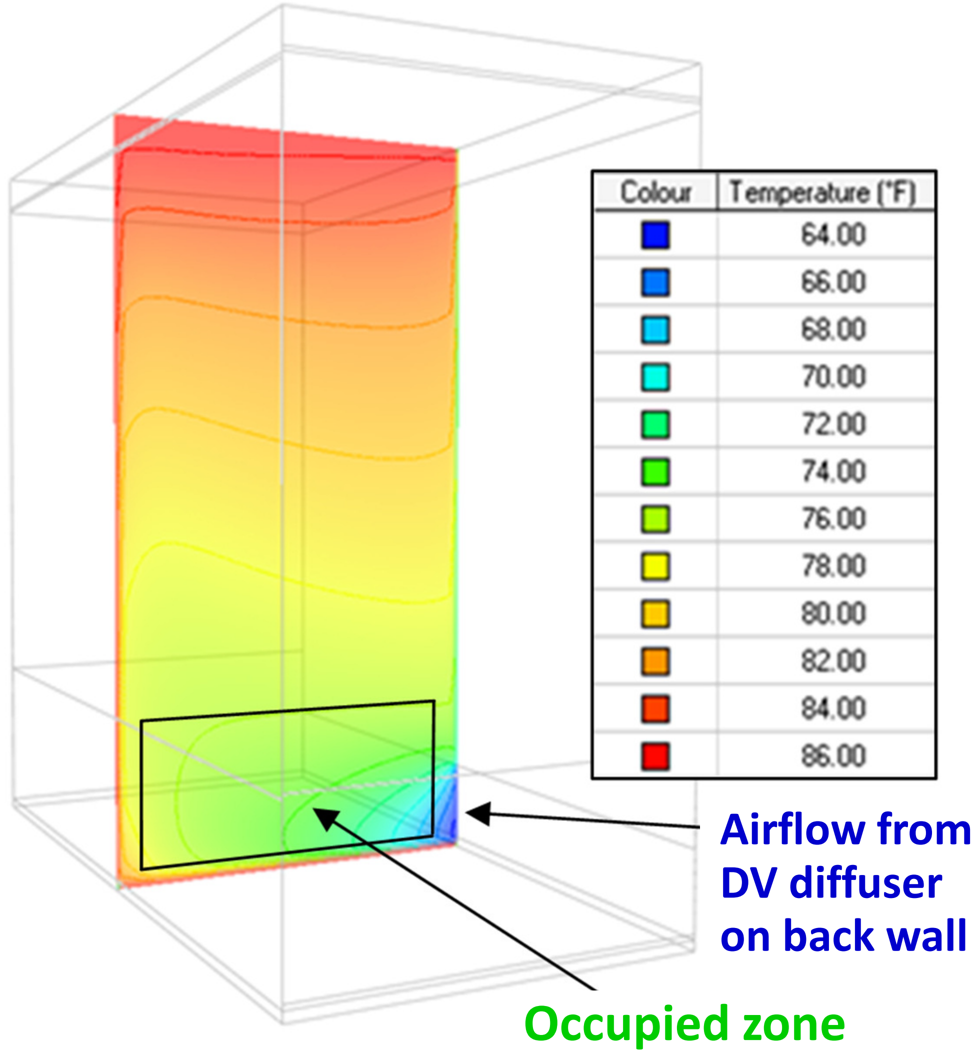


Atrium analysis example: CFD model

- Single volume
  (no zonal subdivisions)

- Initial boundary conditions for each test case taken from selected time step in zonal thermal and HVAC model

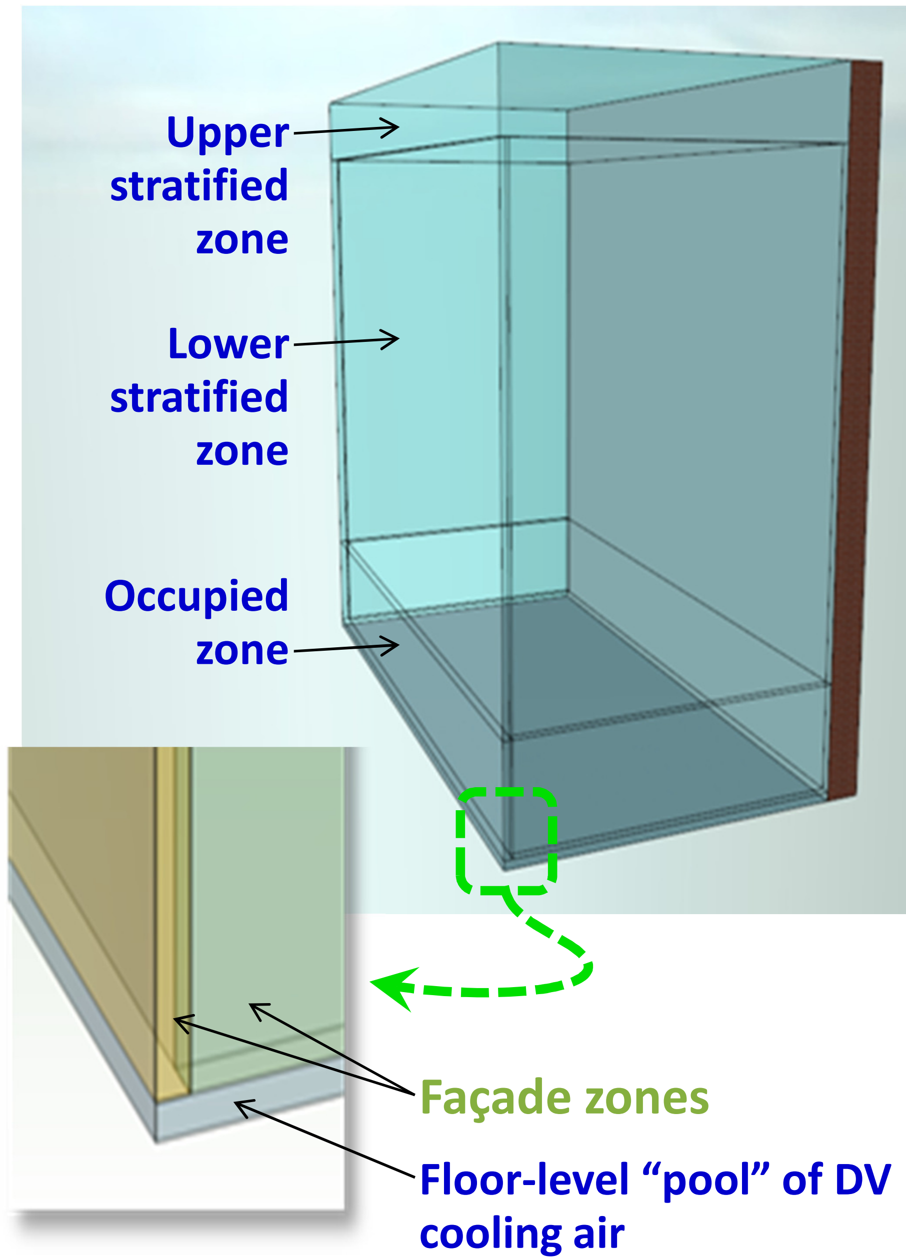
- Initial DV airflow and temperature at large side-wall diffuser set to the same value used in the zonal thermal and HVAC model



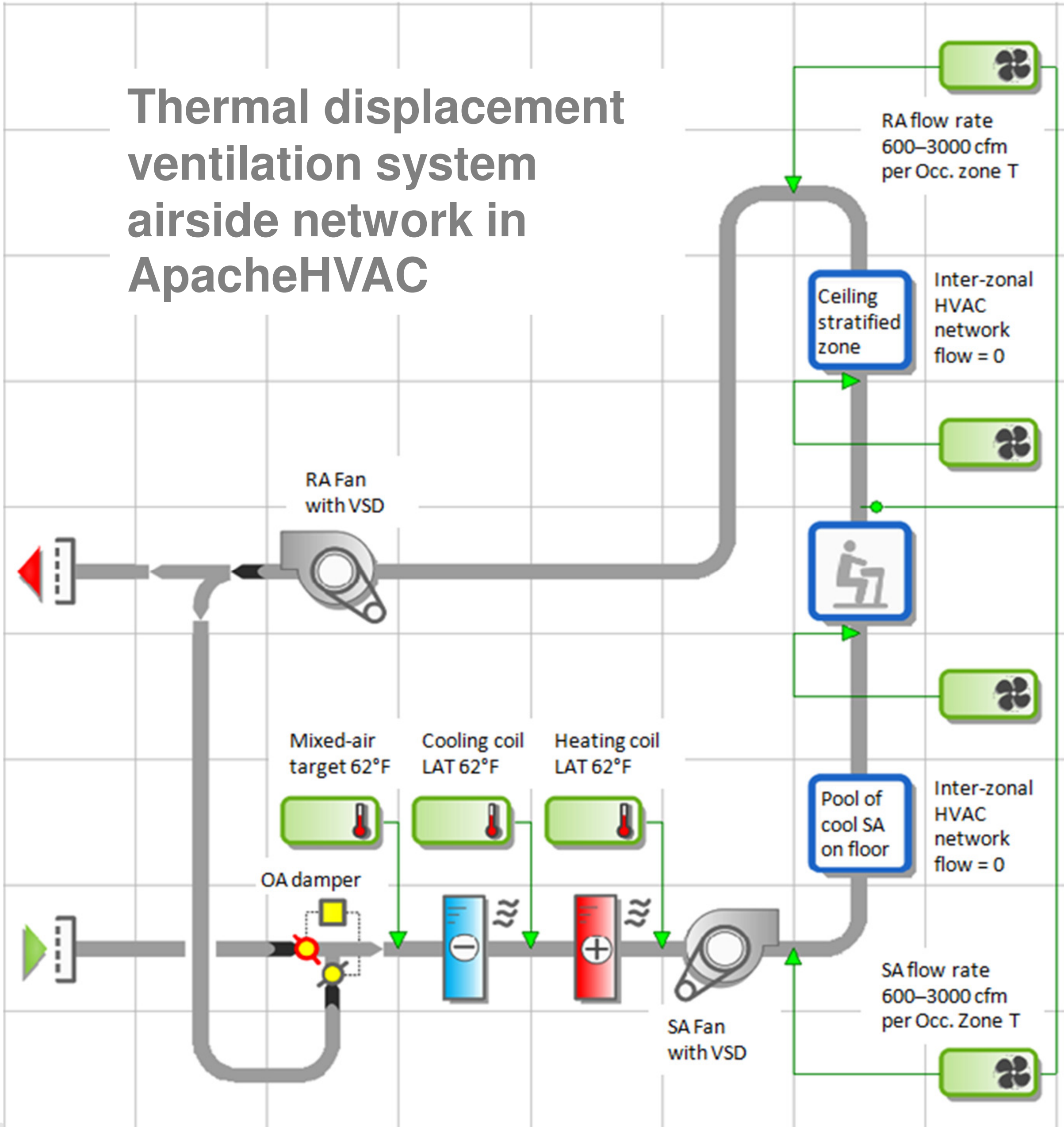
- Temperature at center of occupied zone was basis for comparison of airflow requirements at a given supply air temperature.

Zonal model of atrium for MacroFlo and ApacheHVAC

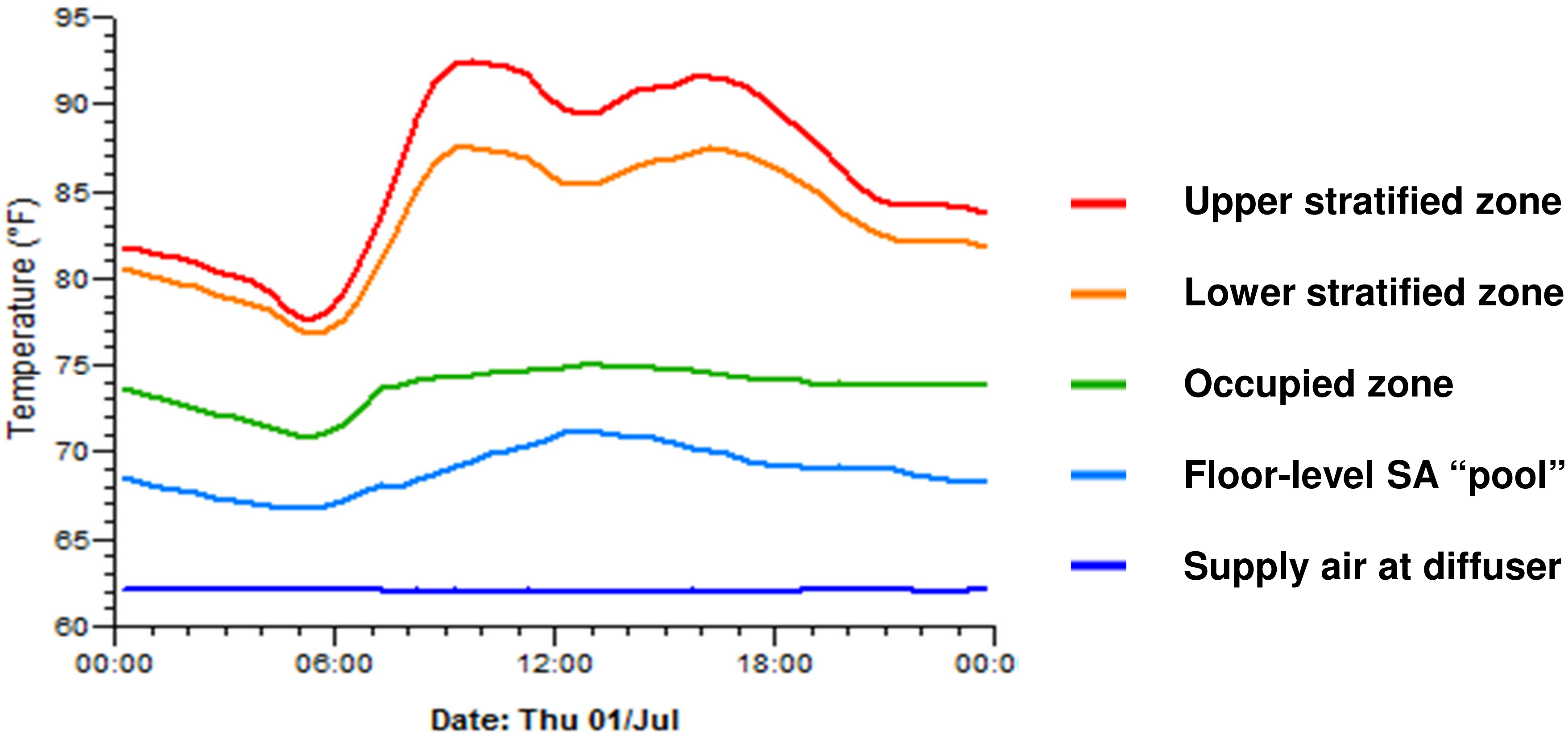
- Subdivision of atrium into 10 zones:
  - 6-in deep "pool" of cooling air (SA introduced here)
  - 7.5-ft Occupied zone above the cooling air pool
  - 28-ft Lower stratified zone
  - 4-ft Upper stratified zone against the ceiling
  - 6-in deep Façade zones for each orientation
    - Matching height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



Atrium HVAC system model

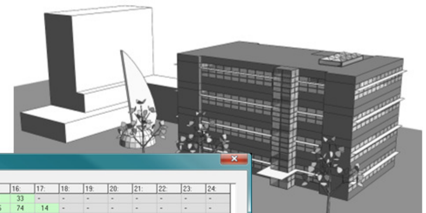


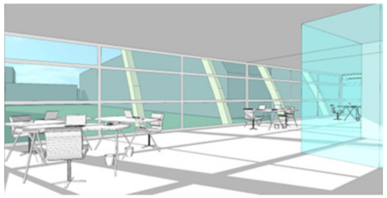
Atrium zone temperatures: Zonal method with MacroFlo + ApHVAC

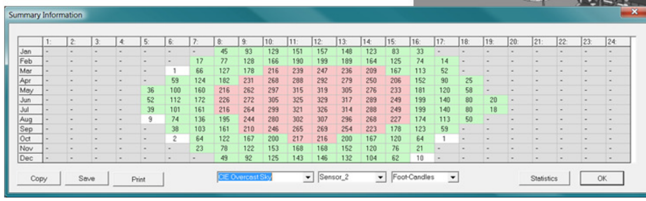


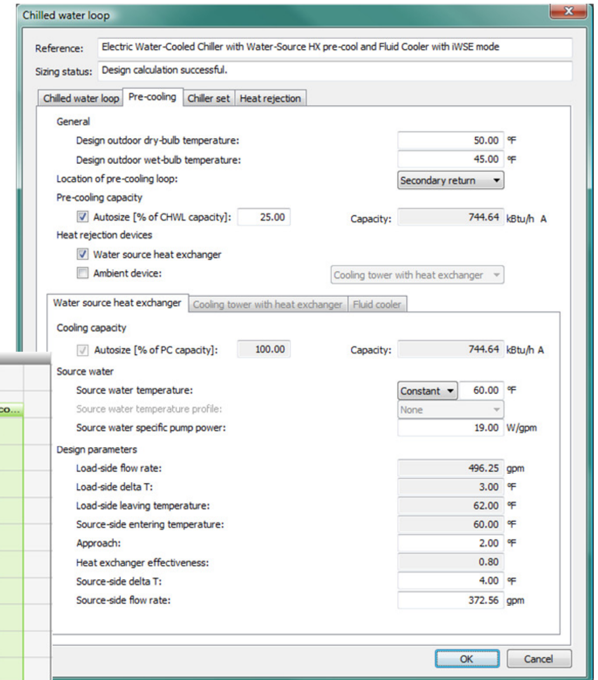
Zone temperatures for the zonal modeling method: 10-zone model with bulk-airflow network.

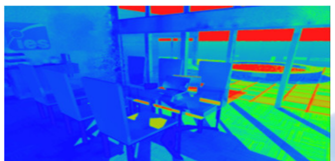
IES <Virtual Environment>
Integrated building performance analysis

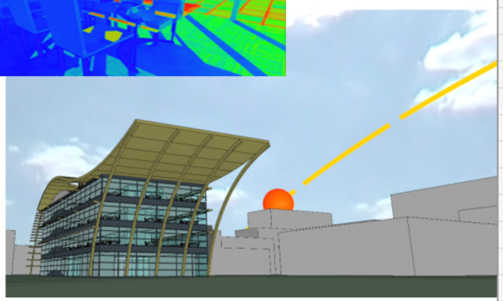


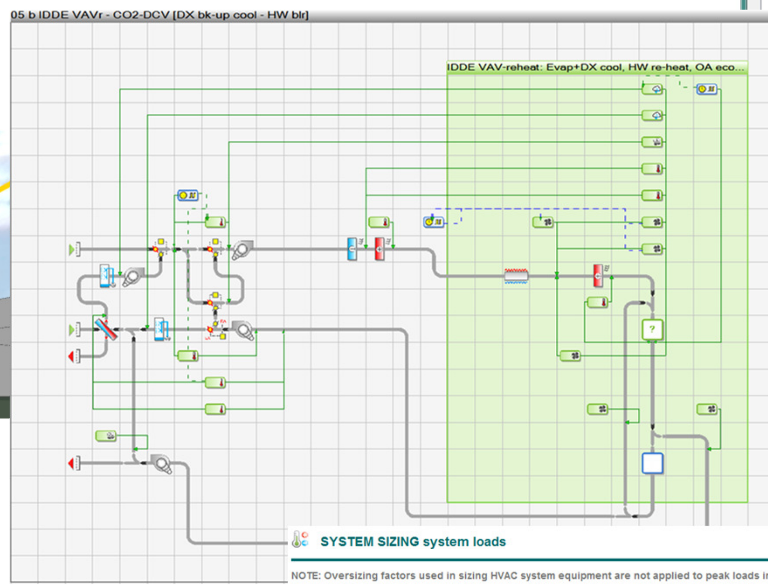


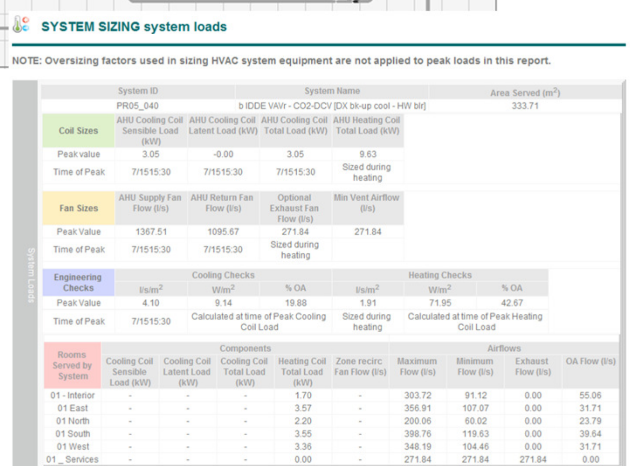












SYSTEM SIZING system loads

NOTE: Oversizing factors used in sizing HVAC system equipment are not applied to peak loads in this report.

System Loads

System ID	System Name	Area Served (m^2)
PR05_040	b IDDE VAVr - CO2-DCV [DX bk-up cool - HW blr]	333.71

Coil Sizes	AHU Cooling Coil Sensible Load (kW)	AHU Cooling Coil Latent Load (kW)	AHU Cooling Coil Total Load (kW)	AHU Heating Coil Total Load (kW)
Peak value	3.05	-0.00	3.05	9.63
Time of Peak	7/1515:30	7/1515:30	7/1515:30	Sized during heating

Fan Sizes	AHU Supply Fan Flow (l/s)	AHU Return Fan Flow (l/s)	Optional Exhaust Fan Flow (l/s)	Min Vent Airflow (l/s)
Peak Value	1367.51	1095.67	271.84	271.84
Time of Peak	7/1515:30	7/1515:30	Sized during heating	

Engineering Checks	Cooling Checks			Heating Checks		
	$l/s/m^2$	W/m^2	% OA	$l/s/m^2$	W/m^2	% OA
Peak Value	4.10	9.14	19.88	1.91	71.95	42.67
Time of Peak	7/1515:30	Calculated at time of Peak Cooling Coil Load		Sized during heating	Calculated at time of Peak Heating Coil Load	

Rooms Served by System	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)	Maximum Flow (l/s)	Minimum Flow (l/s)	Exhaust Flow (l/s)	OA Flow (l/s)
01 - Interior	-	-	-	1.70	-	303.72	91.12	0.00	55.06
01 East	-	-	-	3.57	-	356.91	107.07	0.00	31.71
01 North	-	-	-	2.20	-	200.06	60.02	0.00	23.79
01 South	-	-	-	3.55	-	398.76	119.63	0.00	39.64
01 West	-	-	-	3.36	-	348.19	104.46	0.00	31.71
01 _ Services	-	-	-	0.00	-	271.84	271.84	271.84	0.00