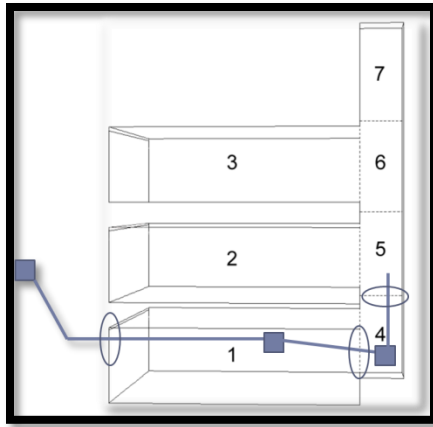


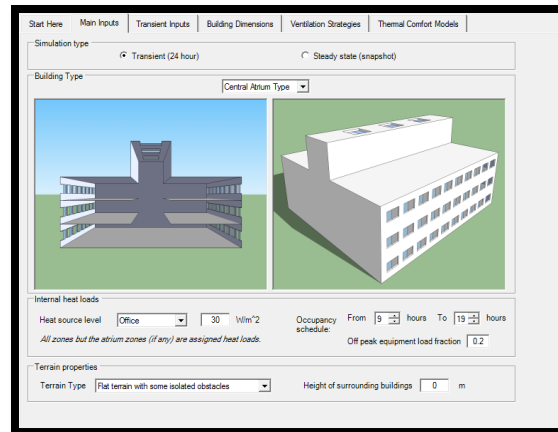
Natural ventilation design tools, applications in commercial buildings

MIT Building Technology Laboratory, Cambridge, USA
Stephen Ray, postdoc

Overview



Intro

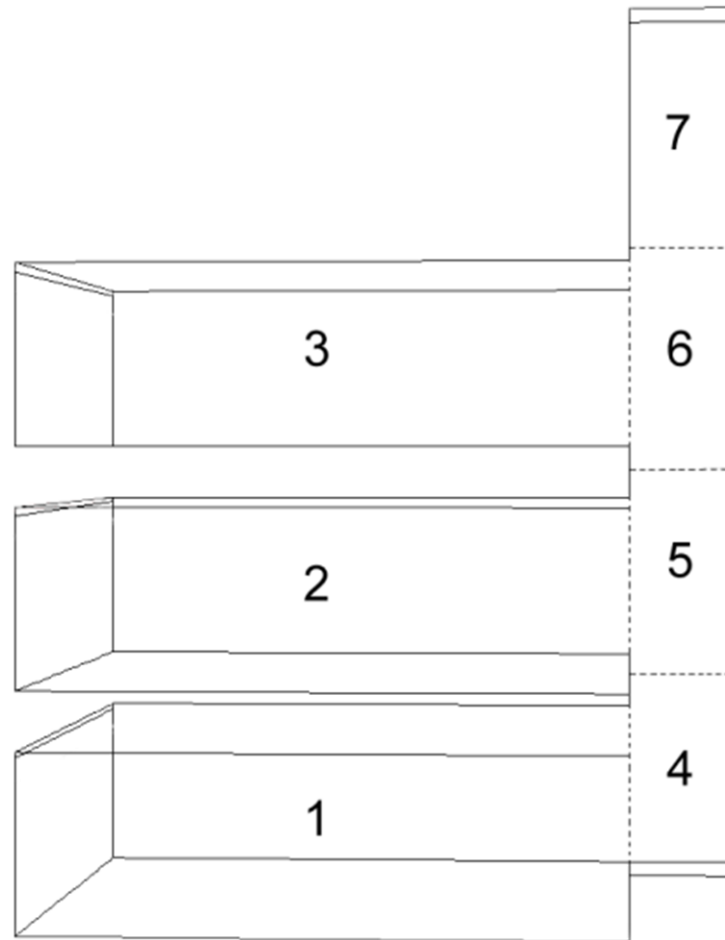


CoolVent

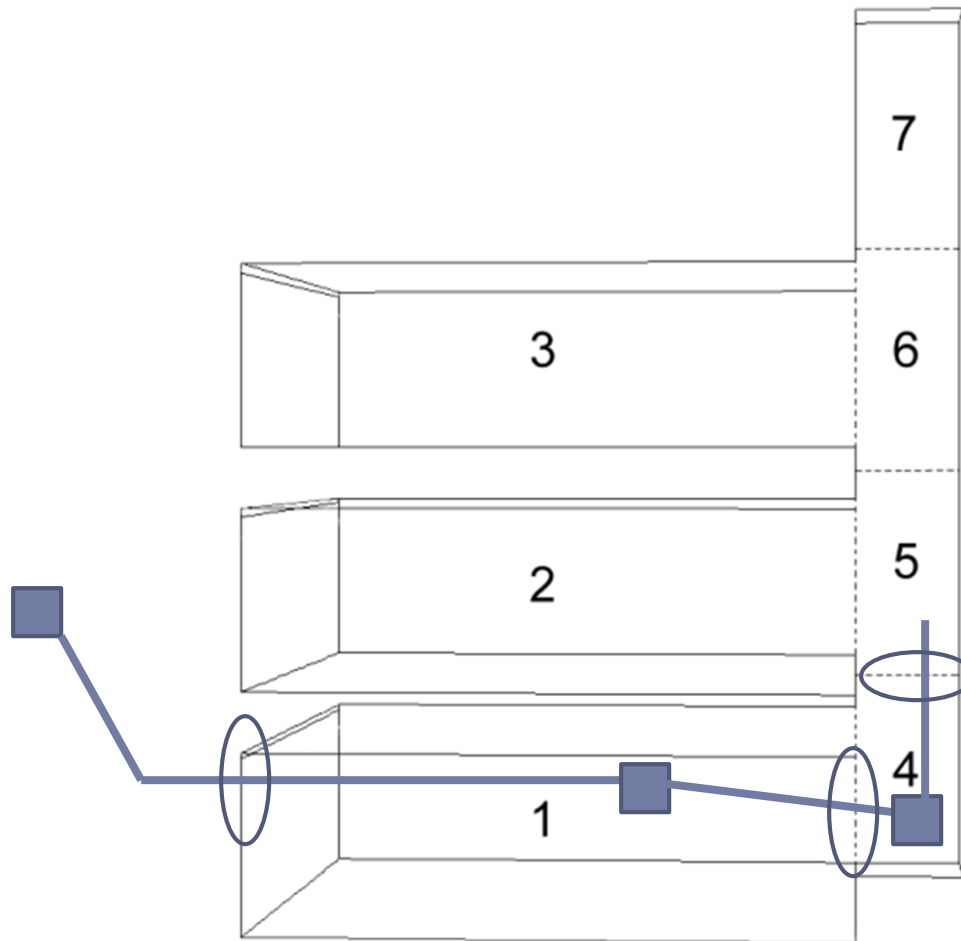


JP bldg

Airflow Network (AFN) models divide space into large zones



Flow pathways connect zones through openings



Conservation equations are used to calculate flow rates and temperatures

Conservation of Momentum
(Bernoulli)

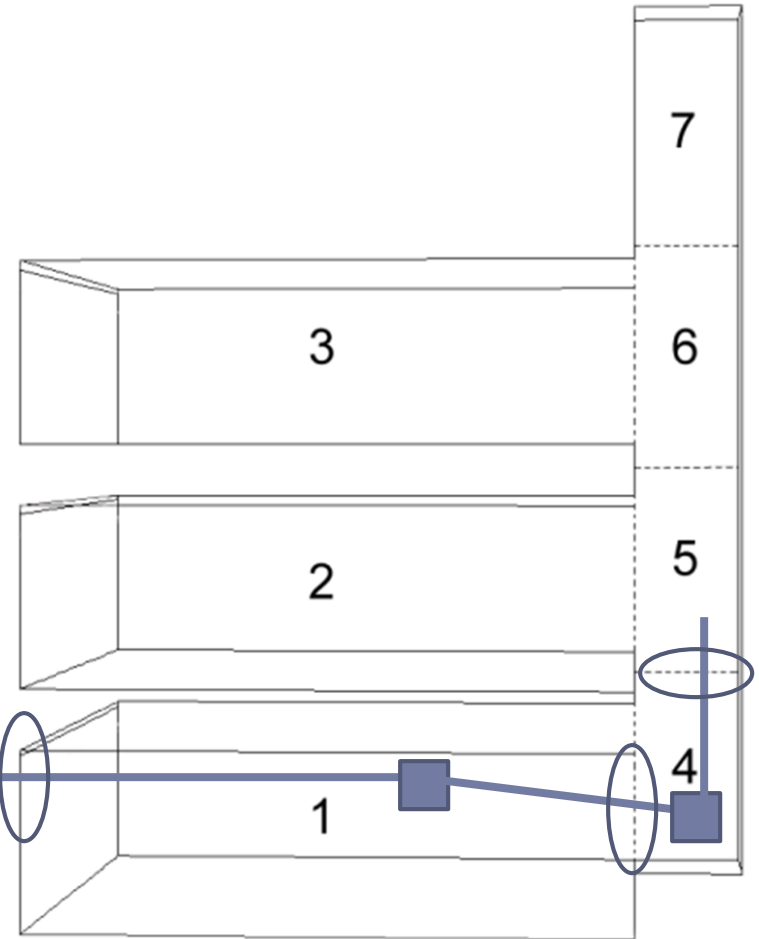
$$\Delta P(T, \text{wind})$$

Orifice Equation

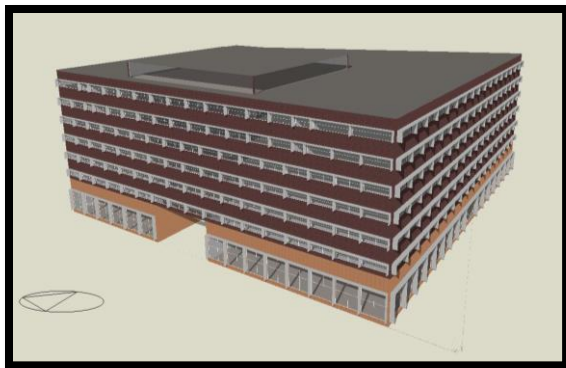
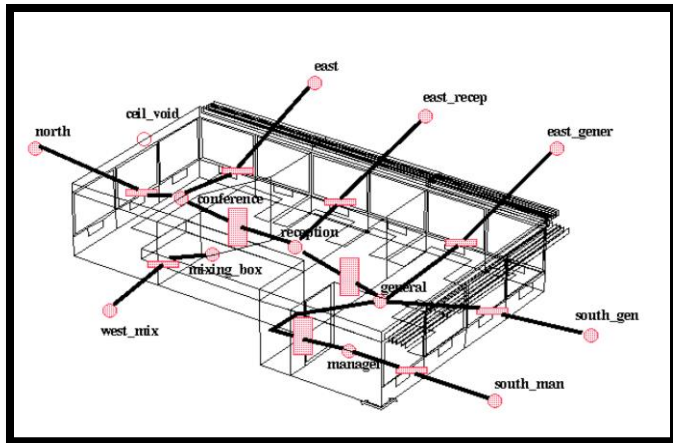
$$\dot{V}(\Delta P, \text{losses})$$

$$\Delta T(\dot{V}, \text{loads})$$

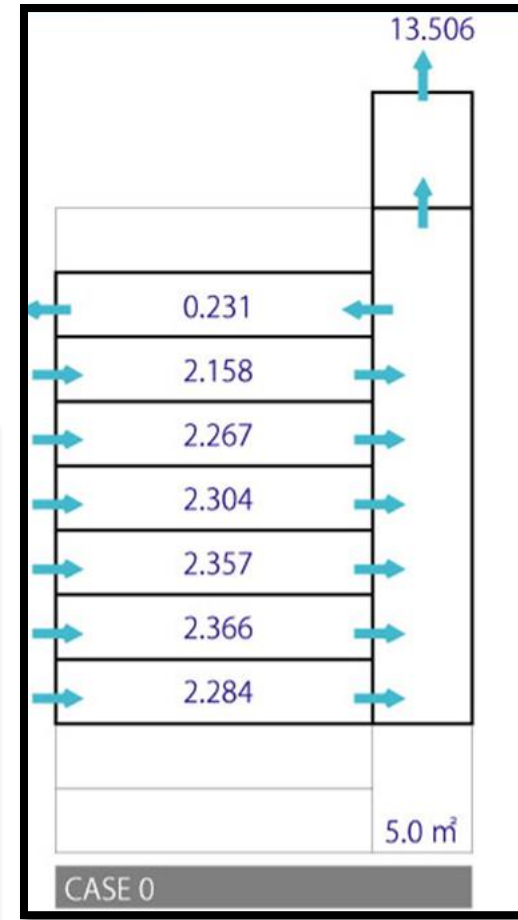
Conservation of Energy



Many AFN models exist, both commercially available and in-house models



A screenshot of a software interface titled "Data Input Form". The interface has several tabs: "Start Here", "Main Inputs", "Transient Inputs", "Building Dimensions", "Ventilation Strategies", and "Thermal Comfort Models". The "Main Inputs" tab is active. It shows a "Simulation type" section with "Transient (24 hour)" selected. Below that is a "Building Type" section with a dropdown menu set to "Chimney Type". There are two 3D renderings of a building. The "Internal heat loads" section shows "Heat Source Level" set to "Office" with a value of "30 W/m²". The "Terrain properties" section shows "Terrain Type" set to "Flat terrain with some isolated obstacles" and "Height of surrounding buildings" set to "5 m".

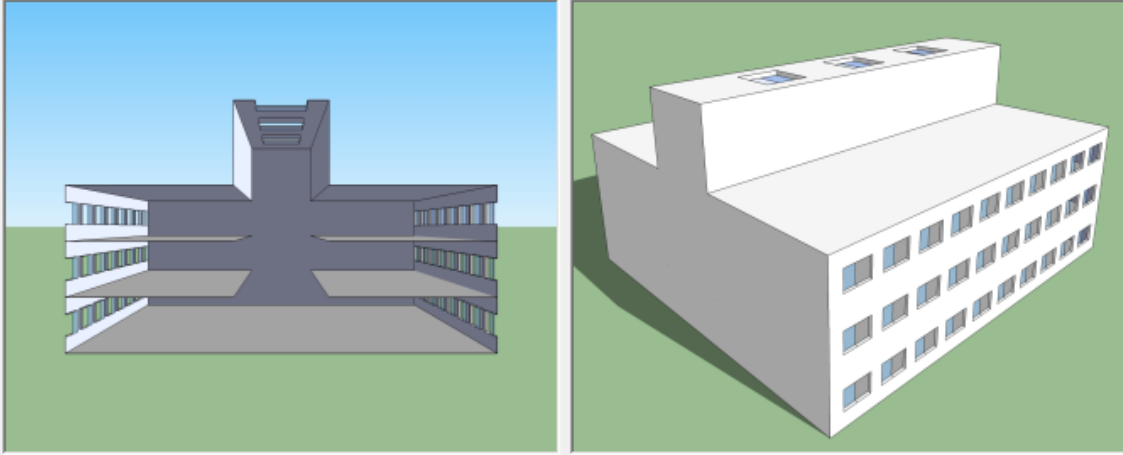


Strength 1: CoolVent easily usable in early design stage

Start Here | Main Inputs | Transient Inputs | Building Dimensions | Ventilation Strategies | Thermal Comfort Models

Simulation type
 Transient (24 hour) Steady state (snapshot)

Building Type
Central Atrium Type



Internal heat loads
Heat source level: Office, 30 W/m²
Occupancy schedule: From 9 hours To 19 hours
Off peak equipment load fraction: 0.2
All zones but the atrium zones (if any) are assigned heat loads.

Terrain properties
Terrain Type: Flat terrain with some isolated obstacles
Height of surrounding buildings: 0 m

Building Dimensions

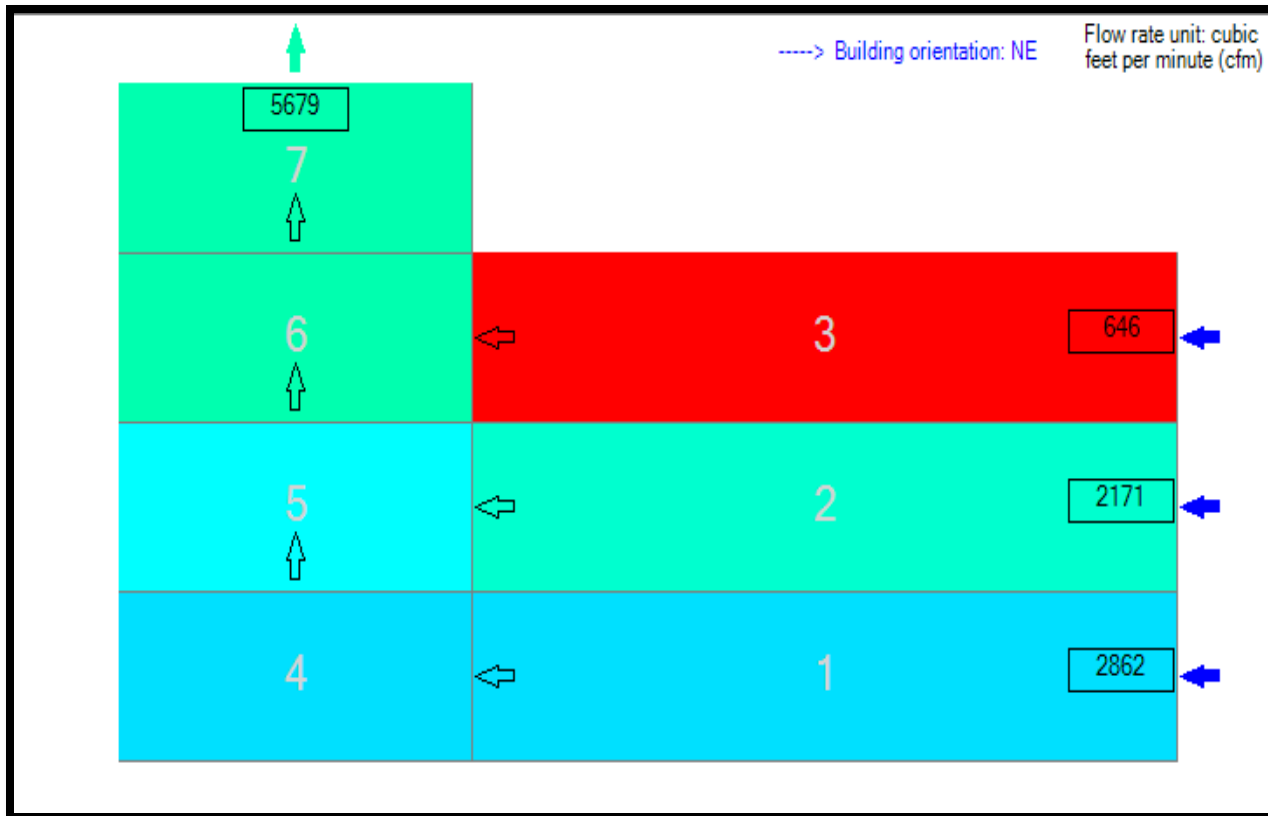
Number of floors	3	?
Floor (bay) width	10	m
Floor-to-floor height	3.5	m
Floor-to-ceiling height	3	m
Floor length	20	m
Chimney width	5	m
Roof height	3	m

Window/Opening Dimensions

Total area of roof openings	4	m ²	+
Total area of operable windows per facade per floor	3	m ²	+
Total glazing area (window frames) per facade per floor	6	m ²	+
Height from floor to mid-opening	1	m	+

Windows have 2 openings spaced vertically

Strength 2: CoolVent provides quick, informative results – temperatures & ACH



Display Settings:

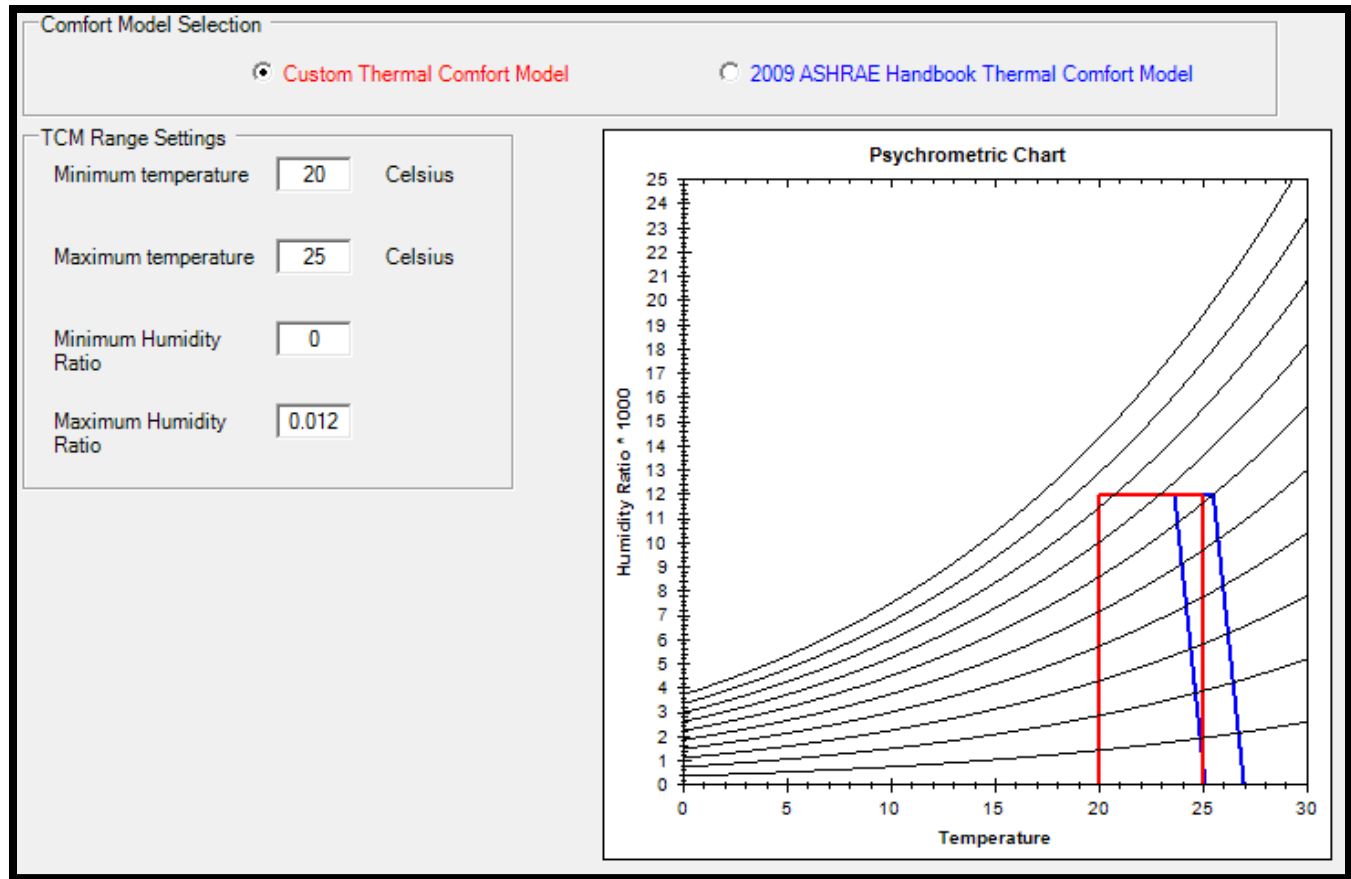
Display Interval: 60 minutes

Airflow Rate Zone Numbers

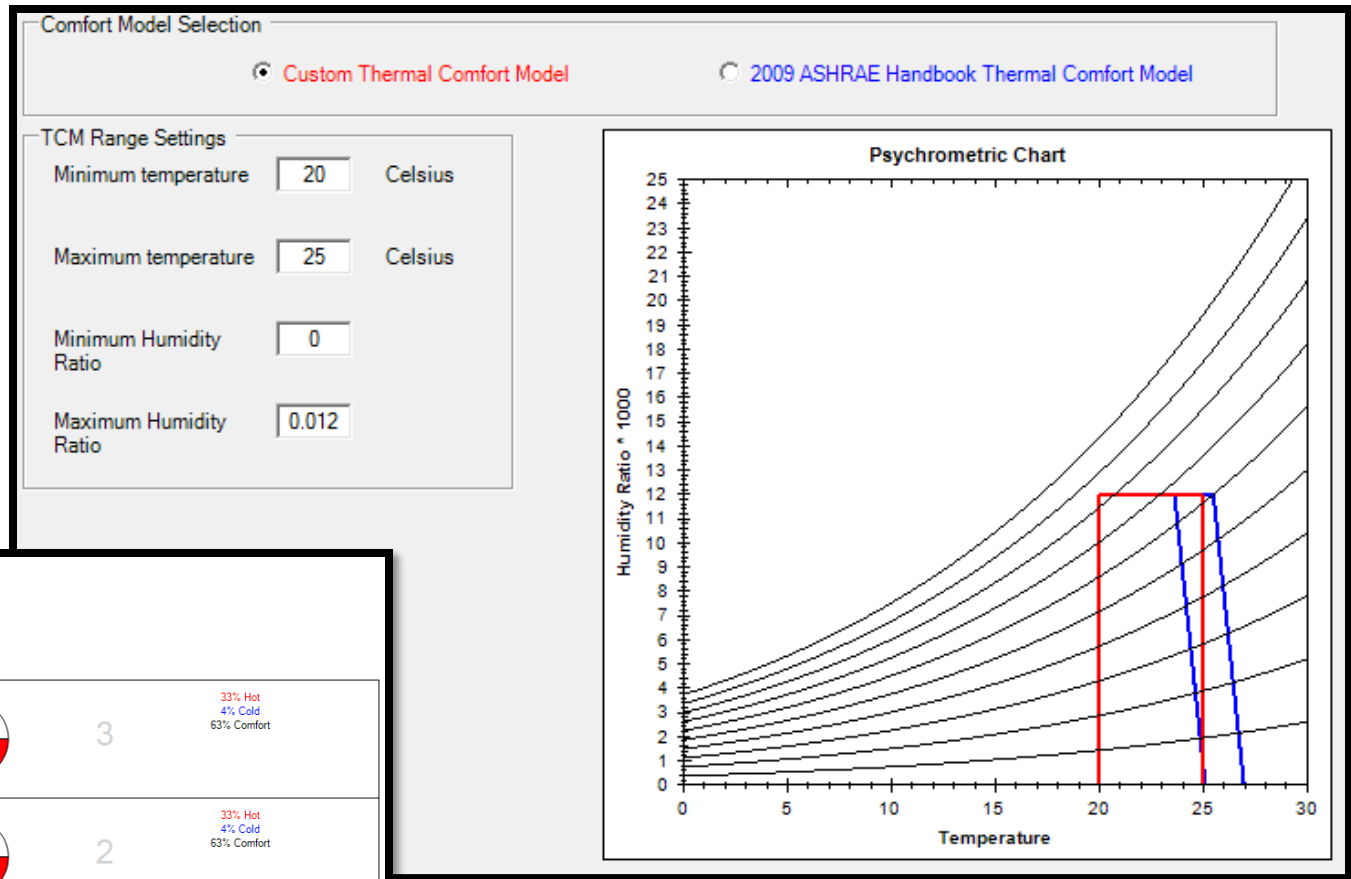
20.0 30.0

Update Colors

Strength 2: CoolVent provides quick, informative results – thermal comfort

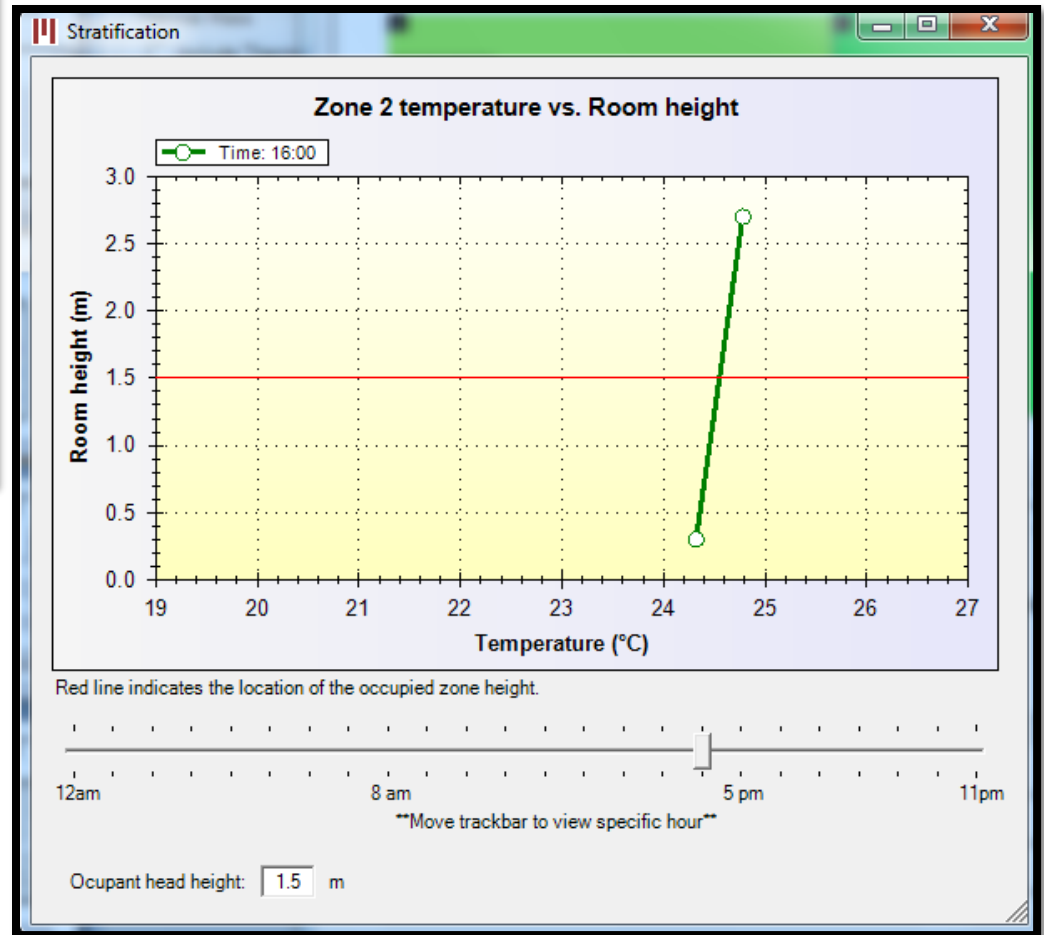
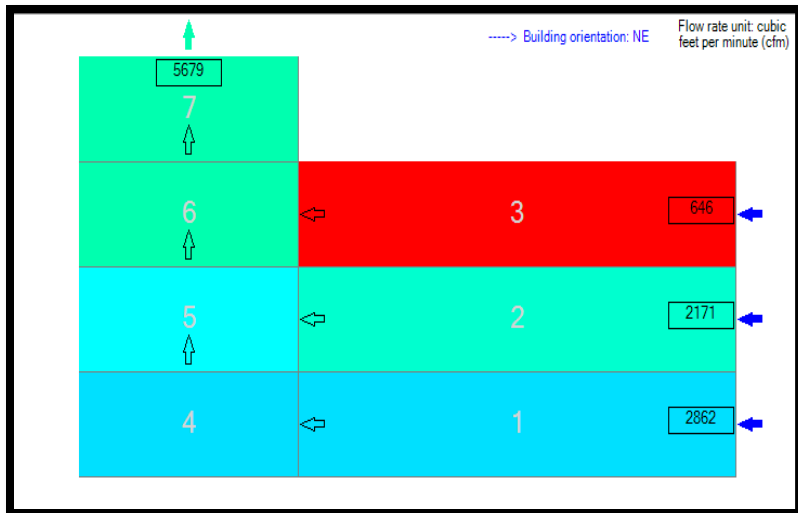


Strength 2: CoolVent provides quick, informative results – thermal comfort

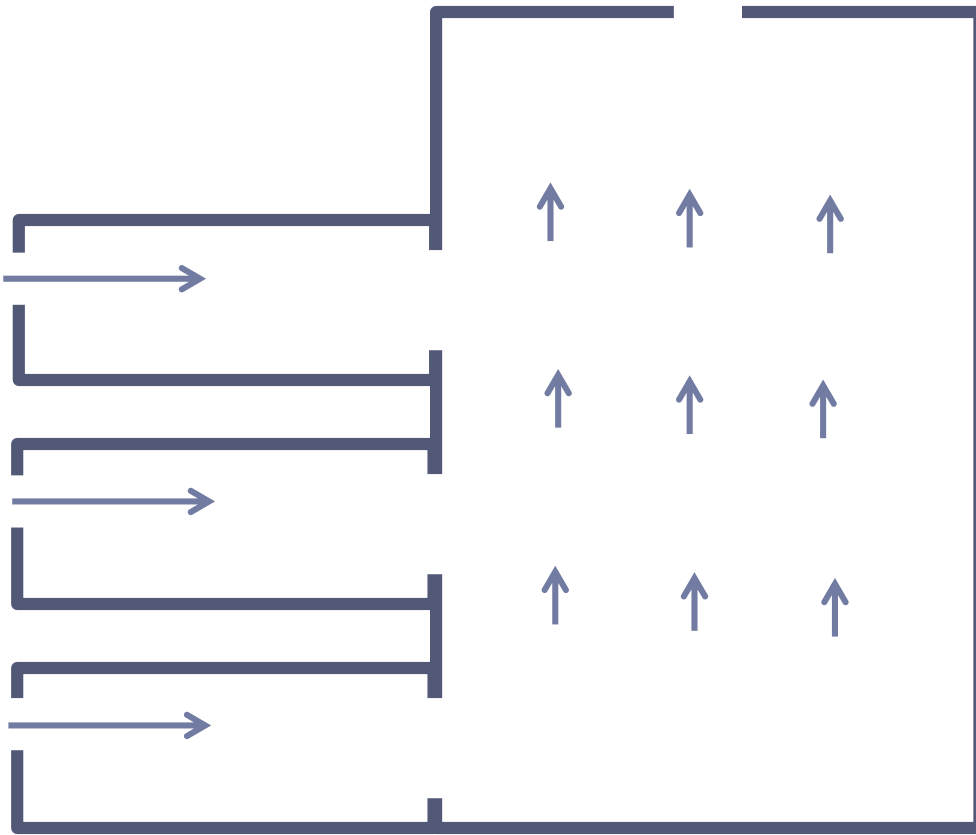


7			
6		3	33% Hot 4% Cold 63% Comfort
5		2	33% Hot 4% Cold 63% Comfort
4		1	33% Hot 12% Cold 55% Comfort

Strength 3: CoolVent predicts zonal vertical temperature distribution – CFD verified



Strength 4: CoolVent models air momentum in ventilation shafts – CFD and model verified

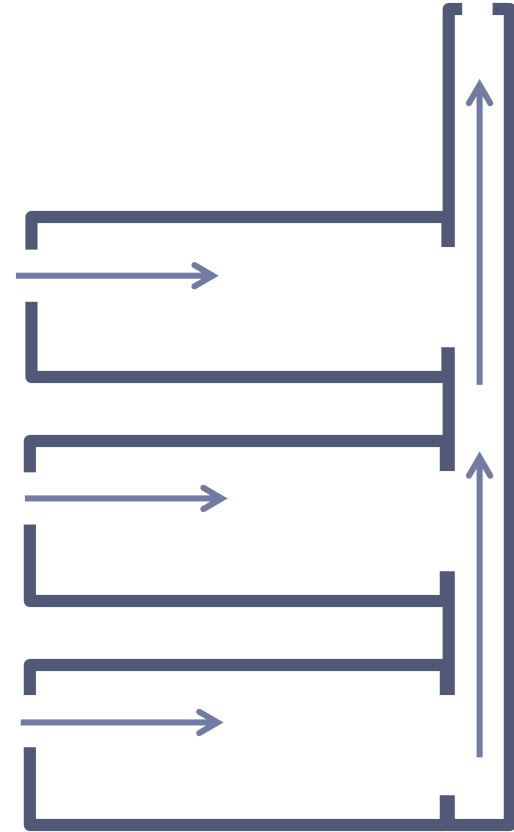


AREA

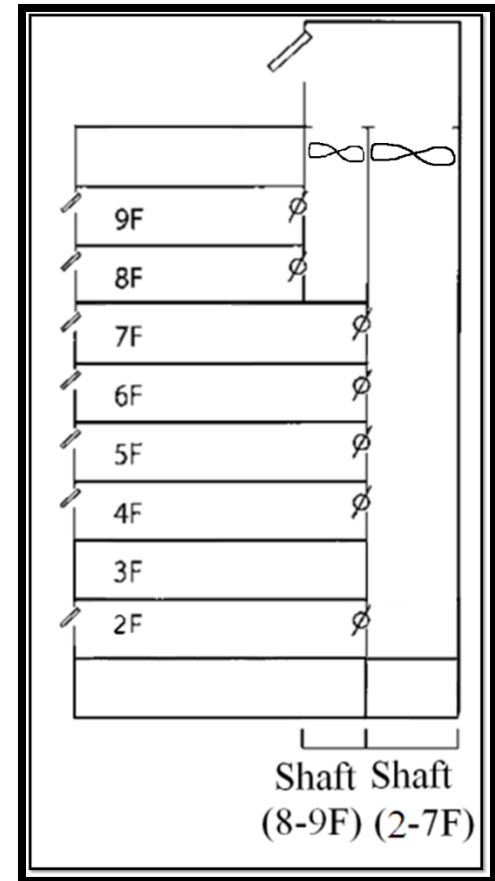
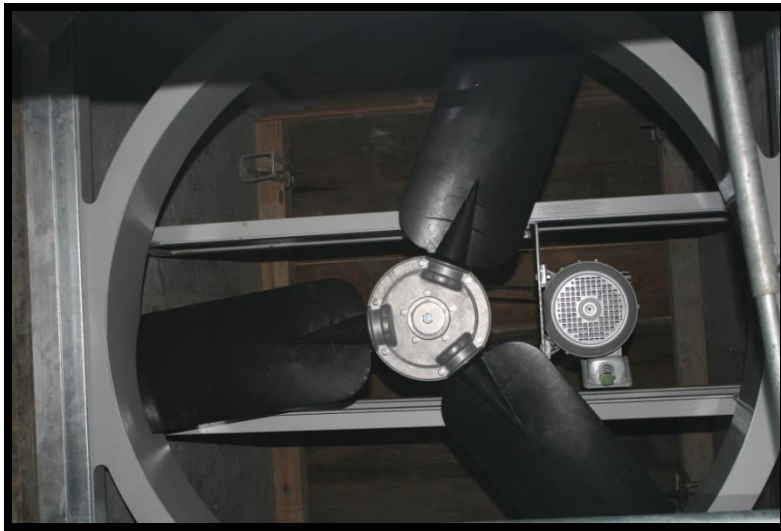
momentum

area

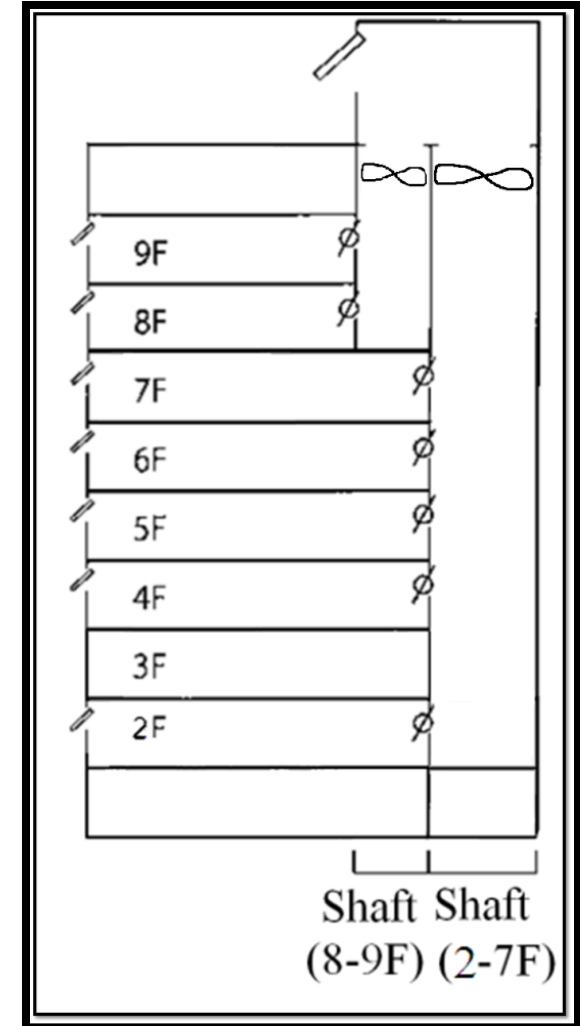
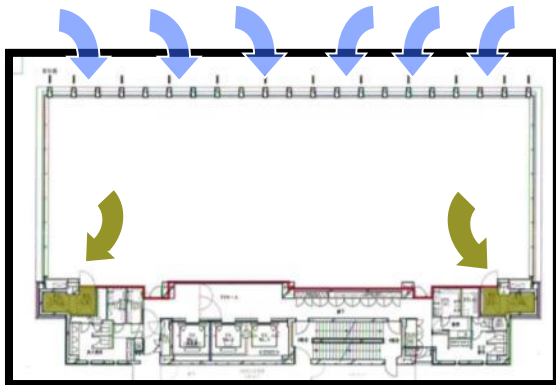
MOMENTUM



Strength 5: CoolVent easily accounts for low-power auxiliary fans



Full scale monitoring of 10 story NV office building in Tokyo w/ 2000+ instruments



Rooftop weather stations not always useful



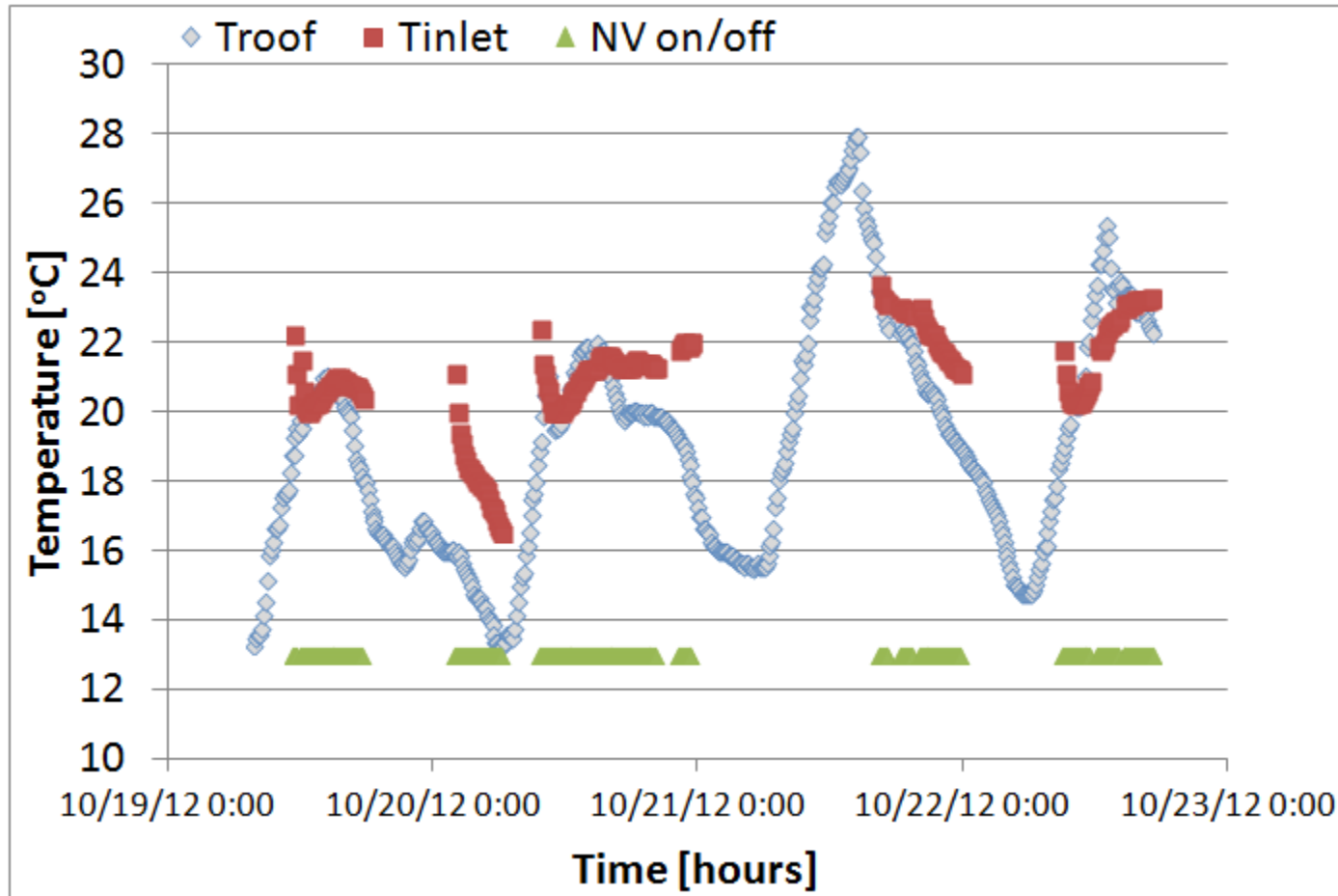
22.9 C

24.3°C	89%RH
CO ₂ 濃度 493ppm	日射量 0.0kW/m ²

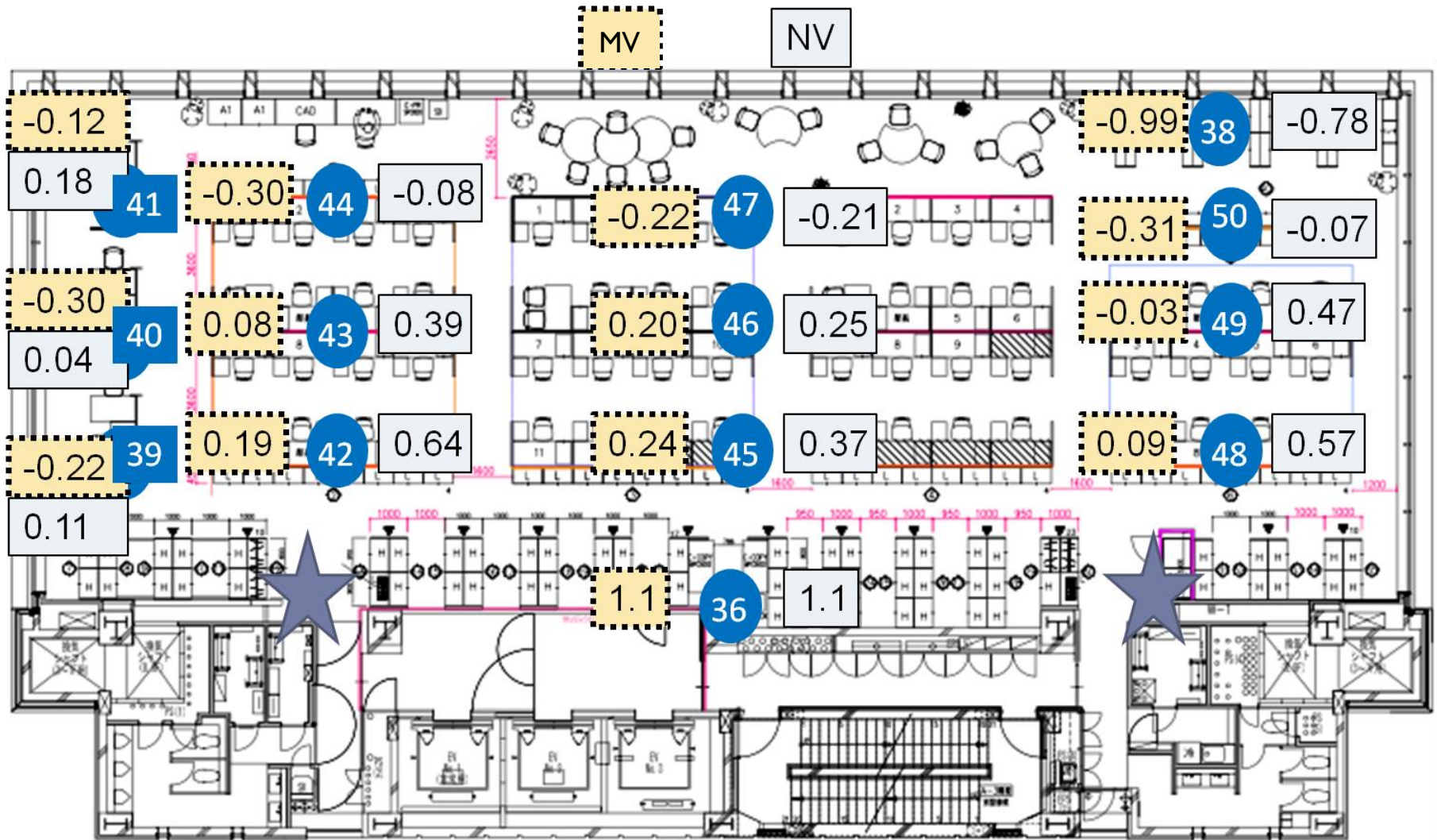


24.3 C

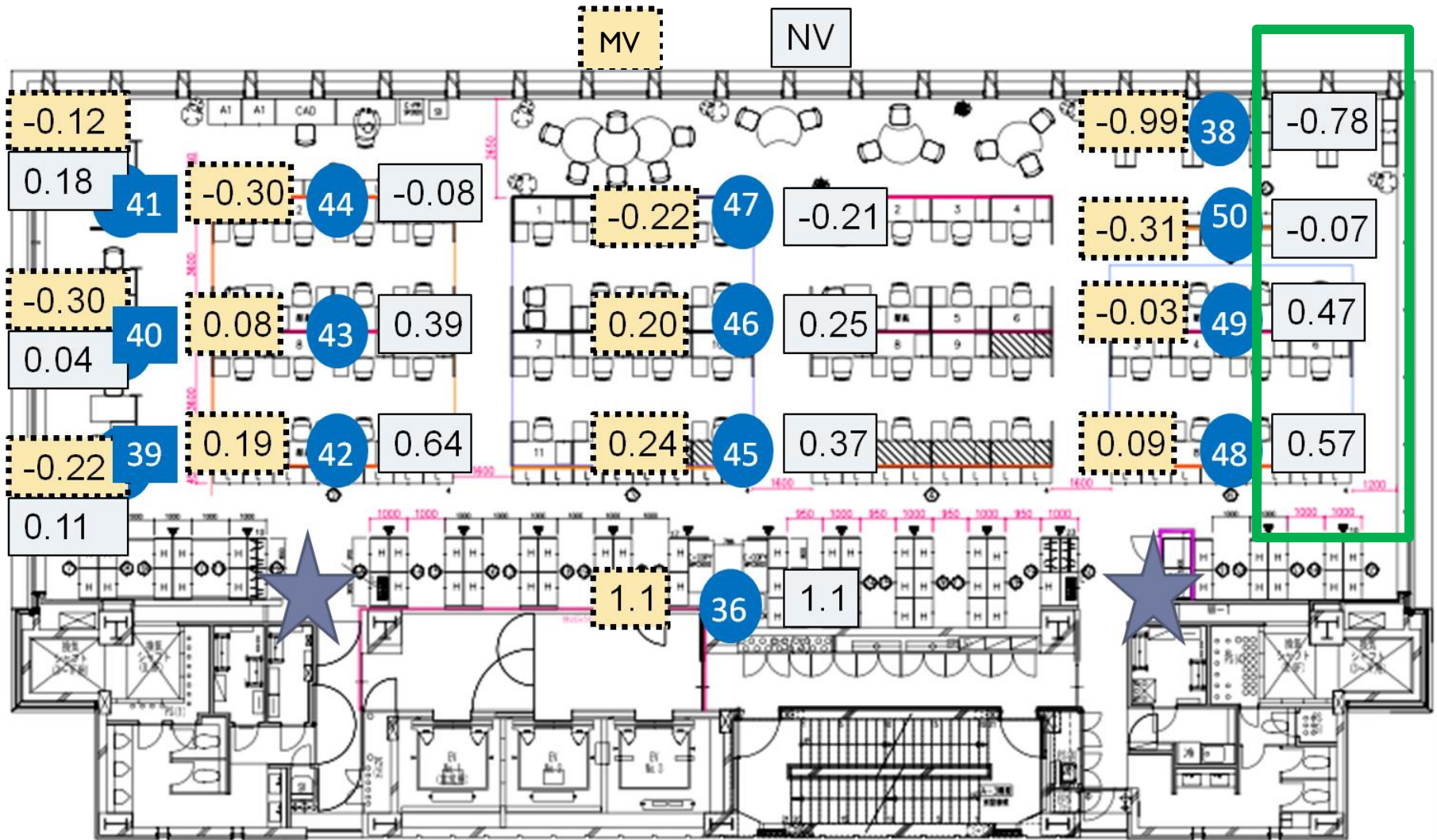
Up to 3 C difference between T_{inlet} and T_{roof} in October



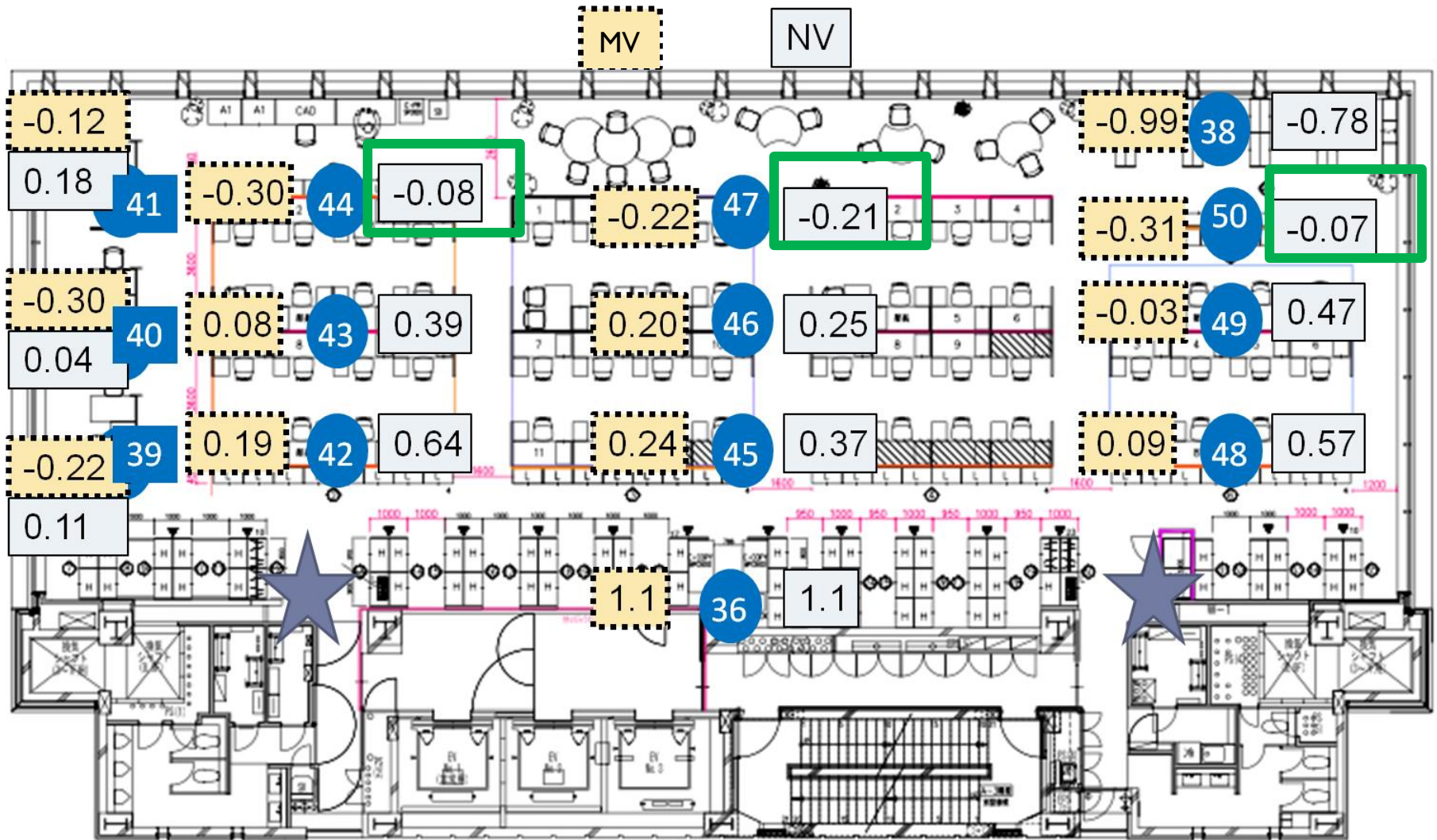
3 week horizontal temperature distribution – measurements at desk level



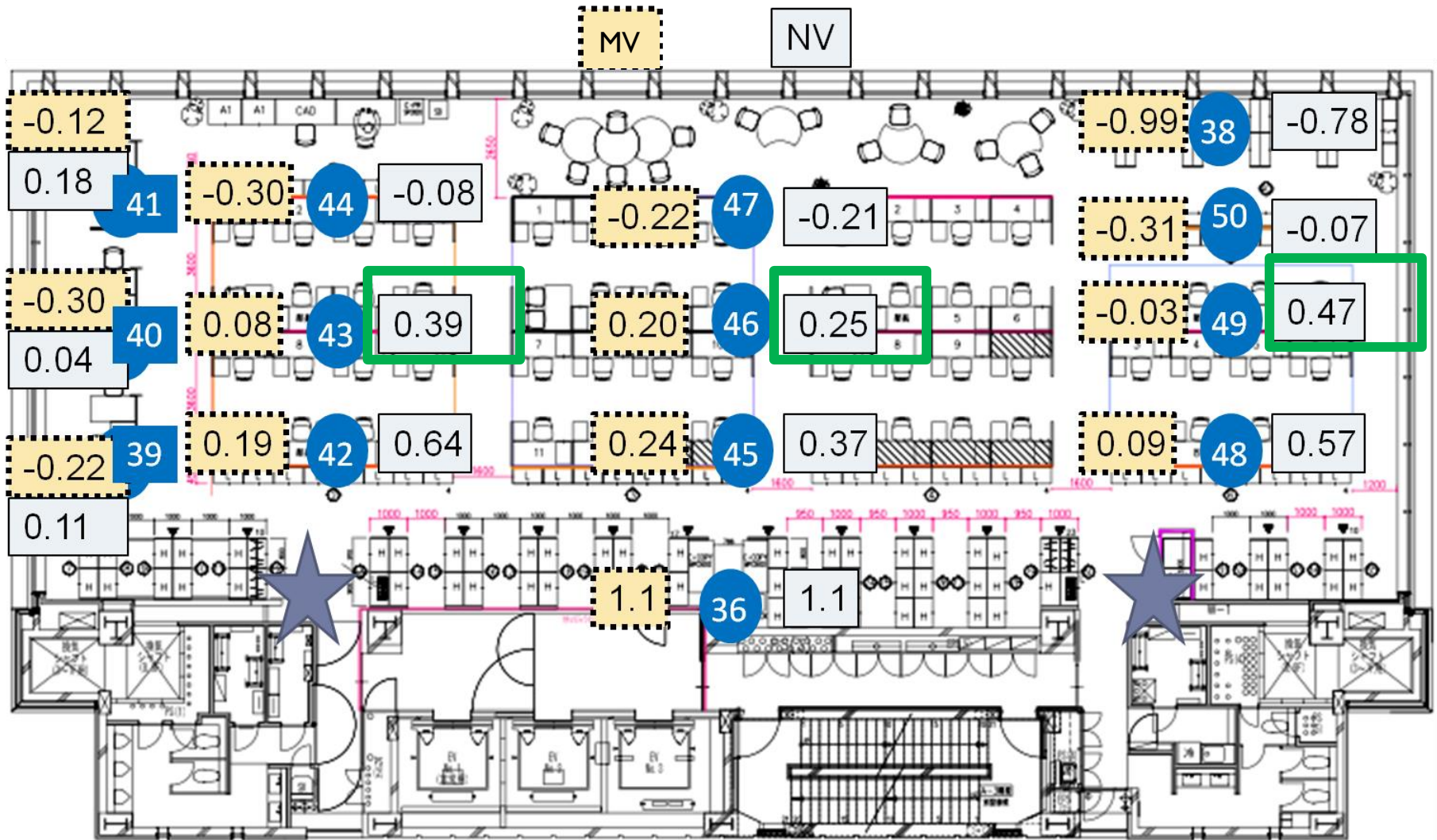
Positive gradient from inlets to back of occupied zone



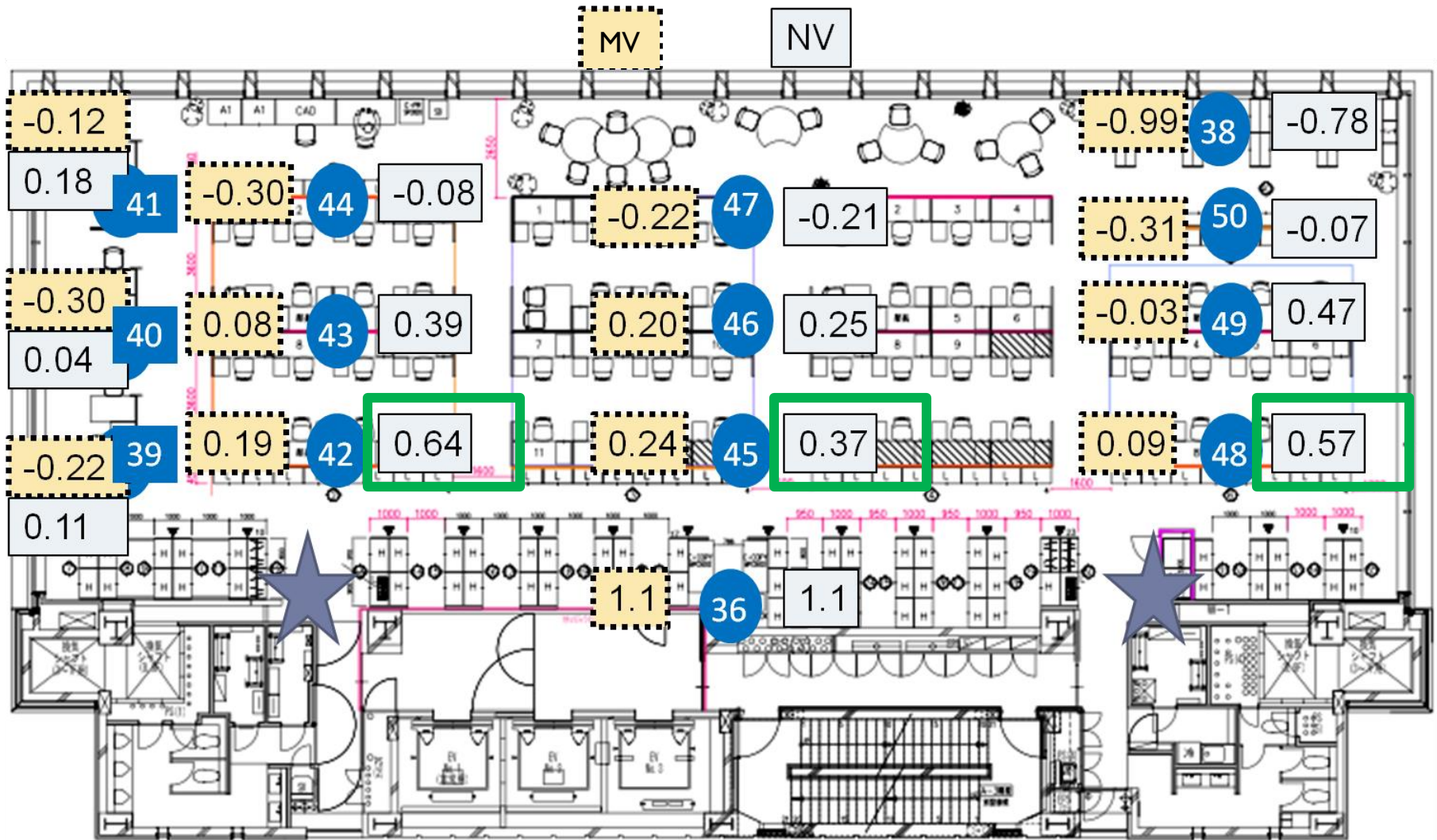
Similar temperatures at similar distances from inlet



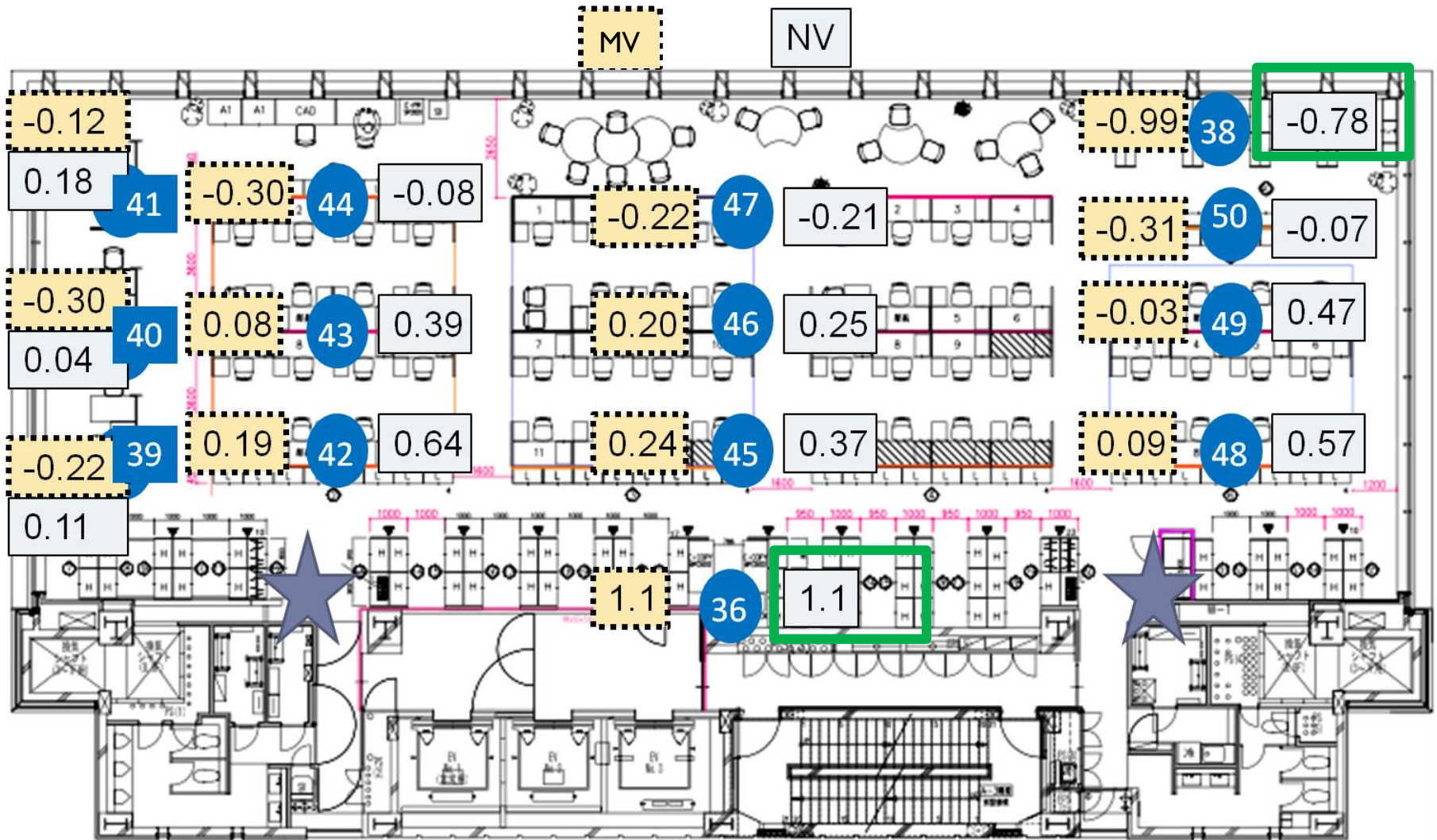
Similar temperatures at similar distances from inlet



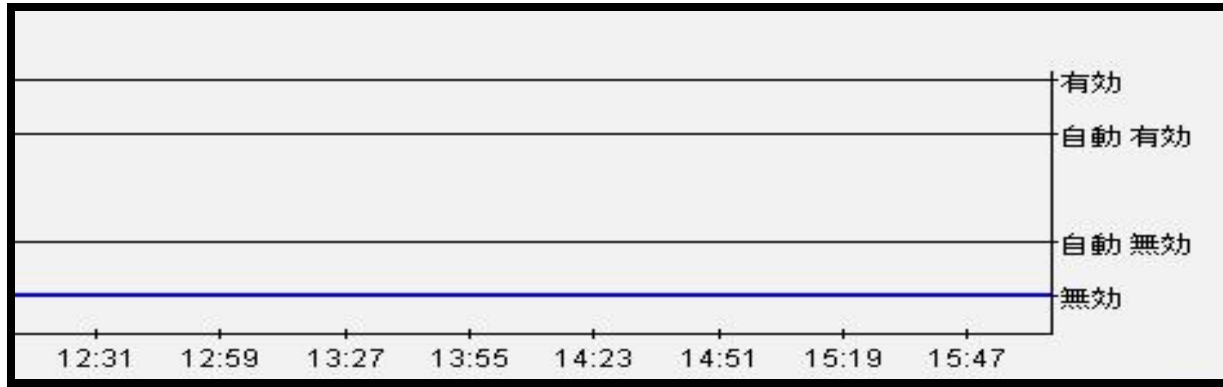
Similar temperatures at similar distances from inlet





Largest difference < 2 C between copy room and window



Occupants can bring strong biases to certain systems: uncomfortable = NV problem



19.3°C	89%RH
CO ₂ 濃度 493ppm	日射量 0.0kW/m ²
 0mm/h	 N 0m/s

DAIKIN
22°C
冷房 設定温度
強

22°C
設定温度

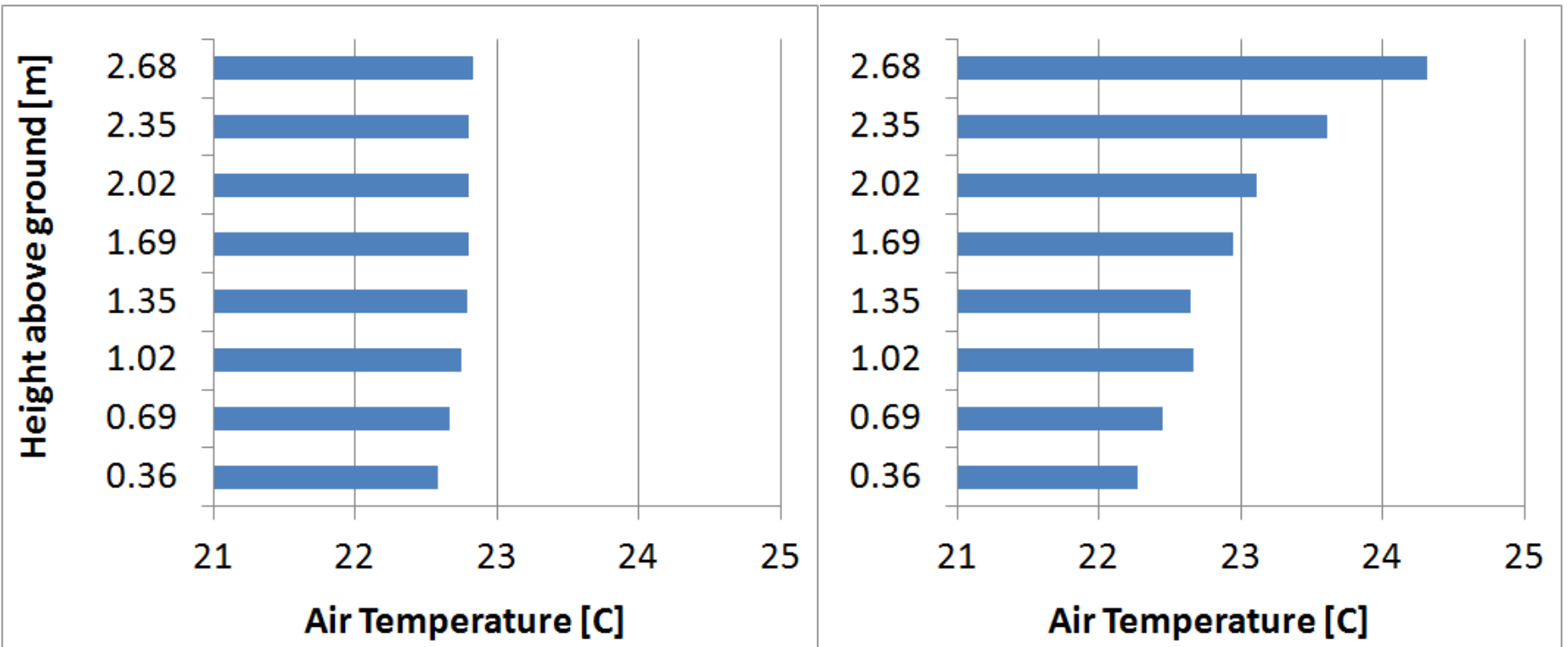
22°C

強

運転切換 温度 運転/停止

メニュー 確定

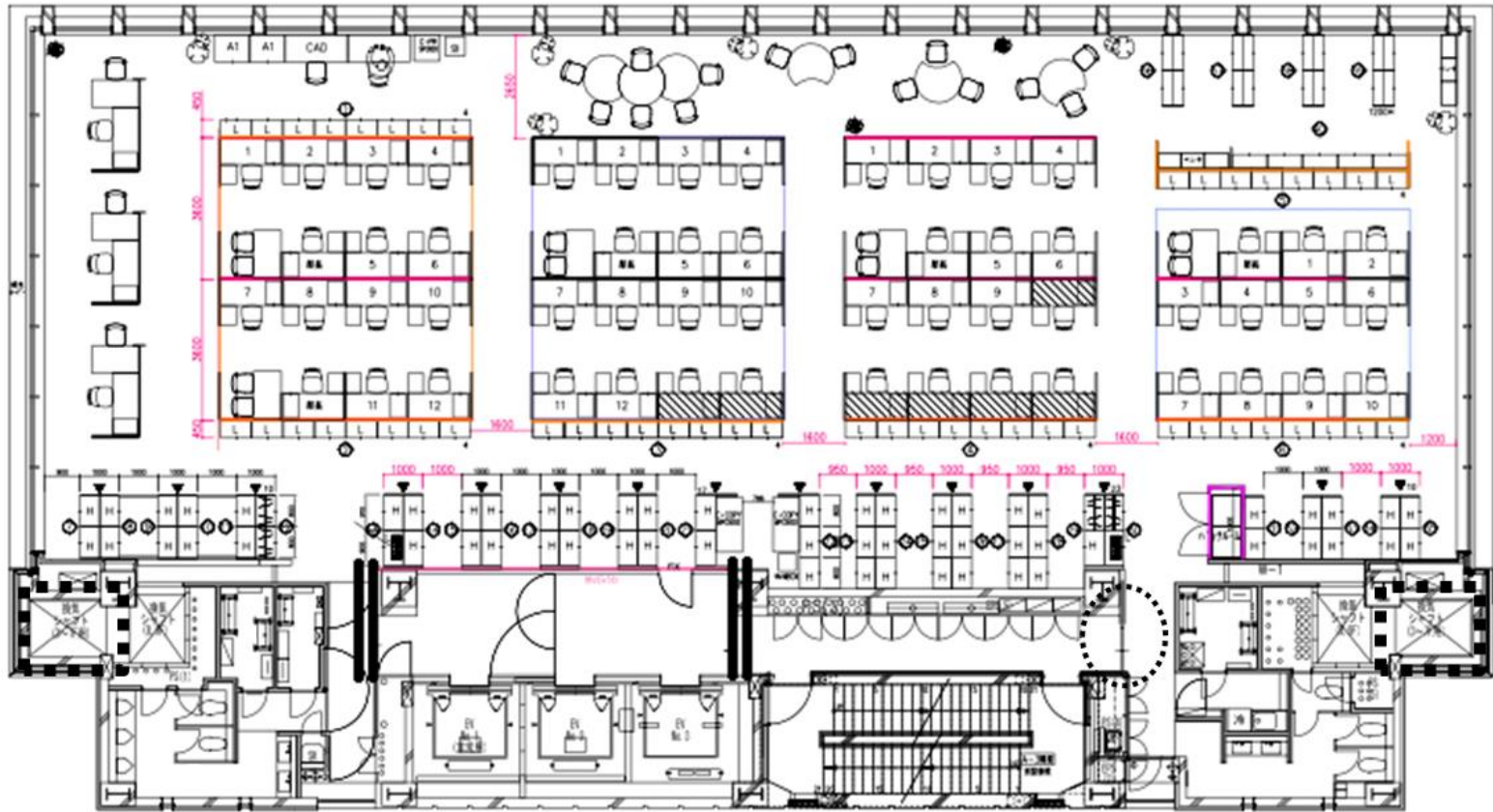
Mech cooling: uniform vertical temps
NV: linear increase in vertical temps



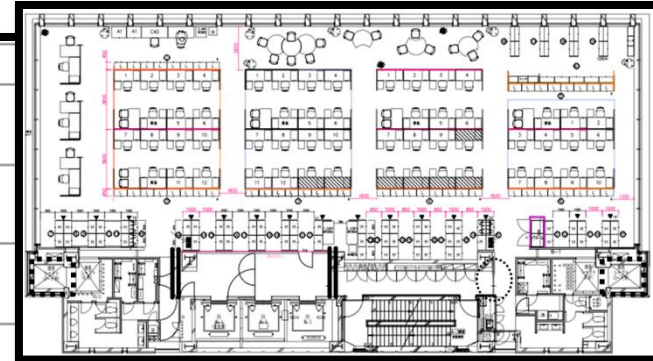
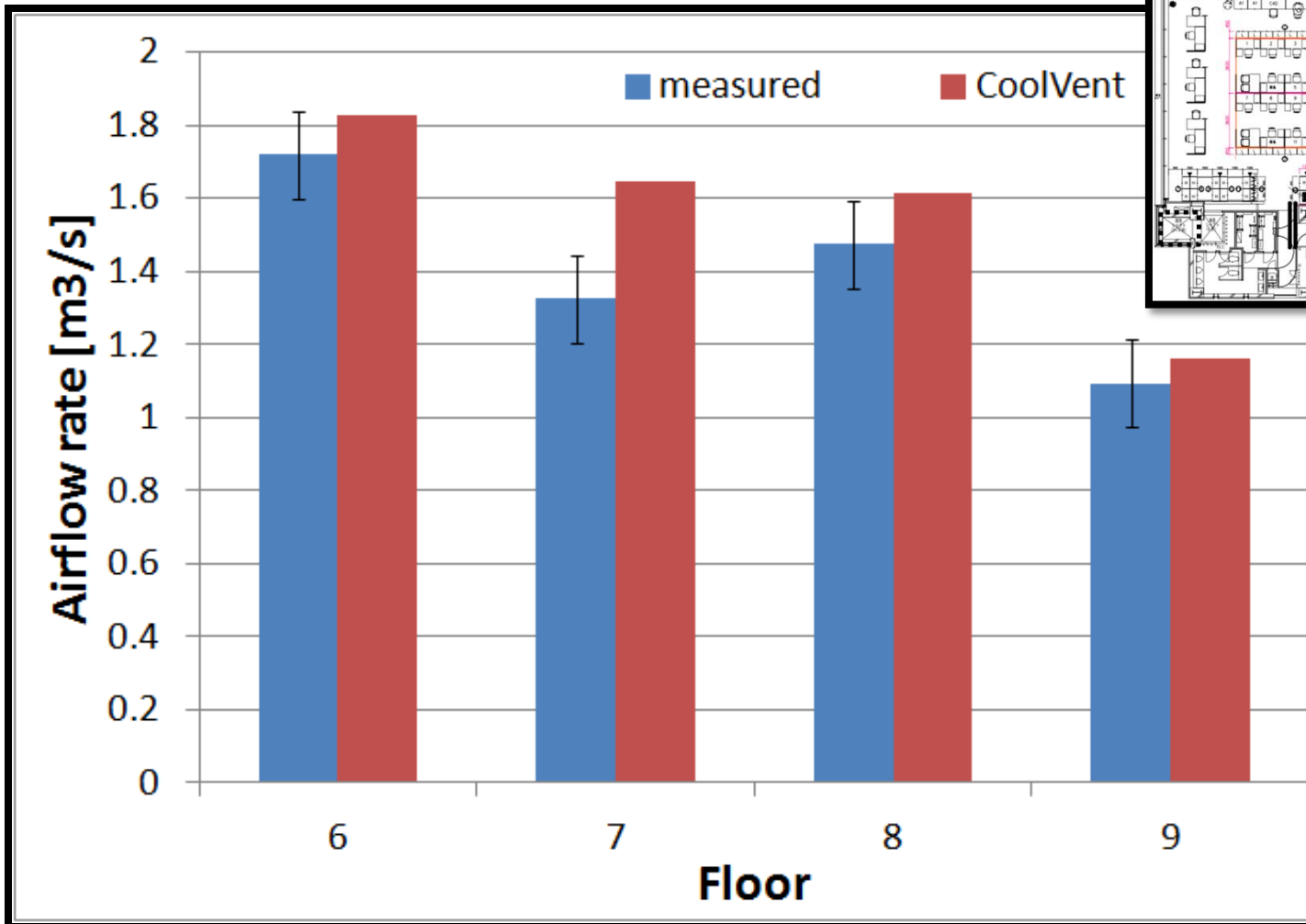
Mechanical Cooling

Natural Ventilation

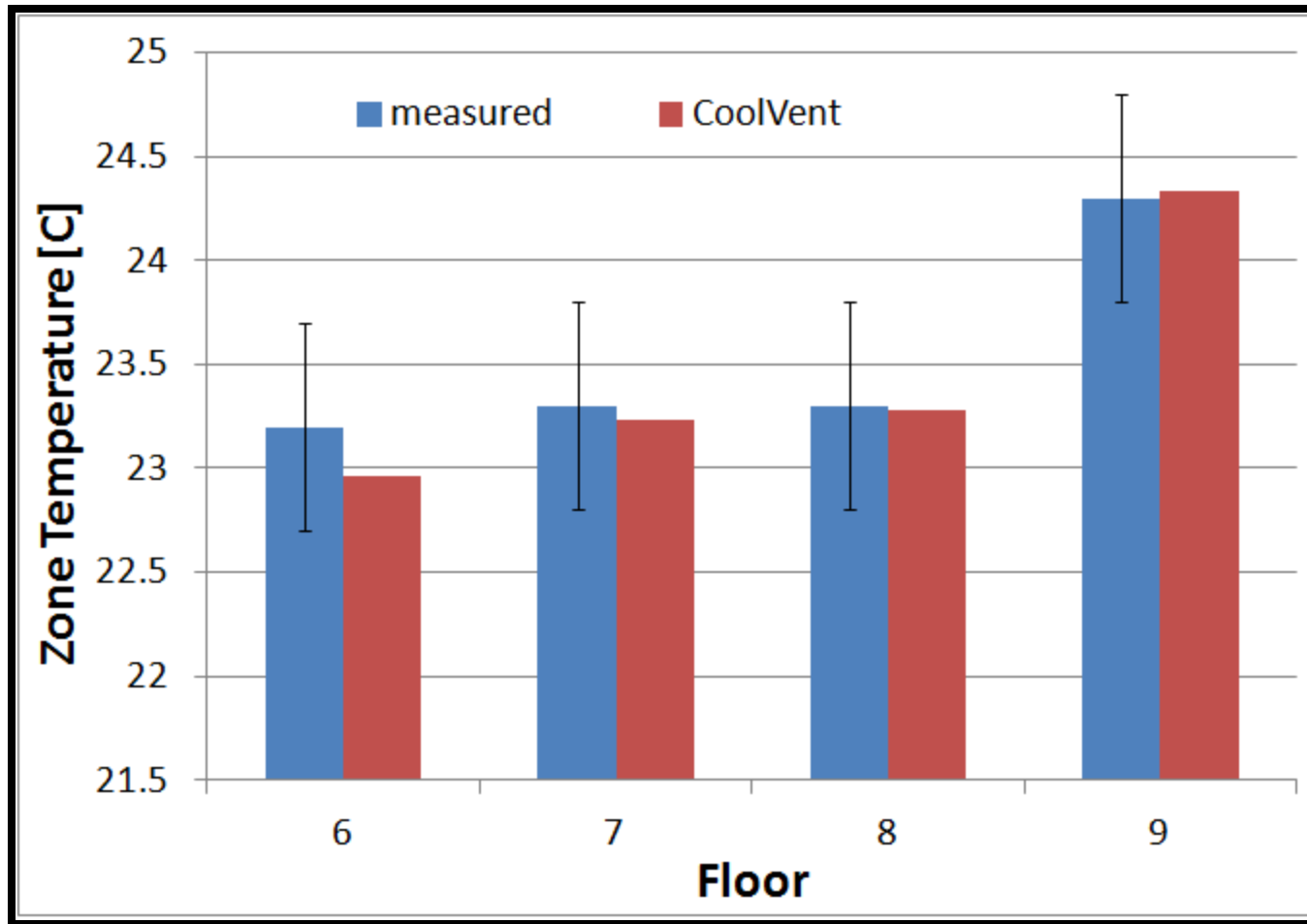
Operation of “non-system” components can be important



Reasonable agreement between CoolVent and measured airflow rates

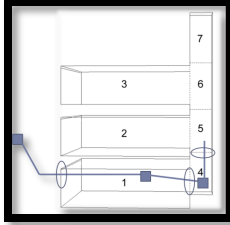


Reasonable agreement between CoolVent and measured air temperatures

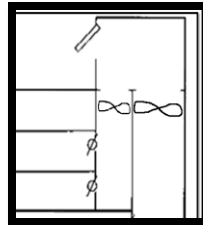
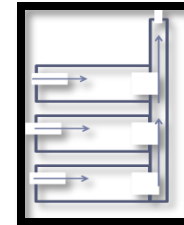
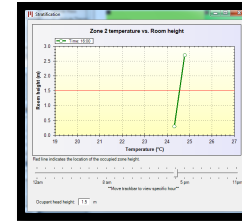
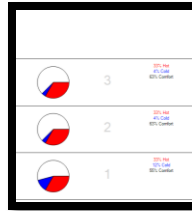
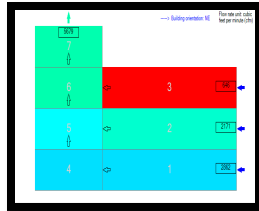
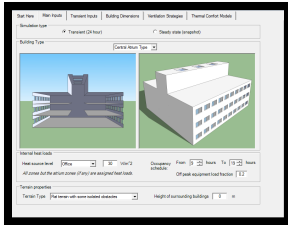


Steve Ray – sdray@mit.edu

Intro



CoolVent



JP bldg

