The impact of solar radiation on inter-flat contaminants transmission characteristics in a high-rise building

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INTRODUCTION

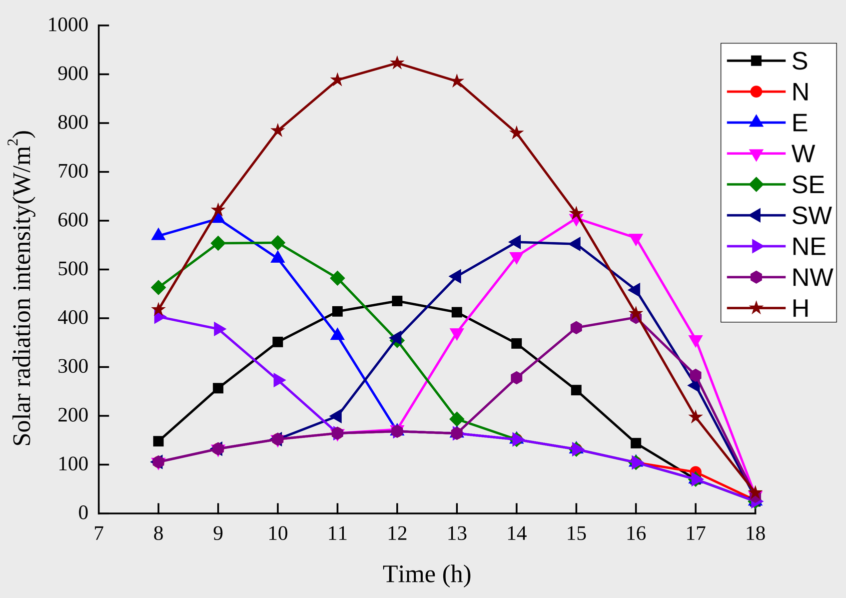
In windless or breezy sunny days, the outer vertical walls of a building could be heated strongly by solar radiation. The flow caused by natural convection adjacent to the heated wall becomes an important mechanism in the creation of wind flows, especially in cities with high-rise buildings. The wall thermal plume could drive the gaseous pollutant releasing from lower floor to upper floors. Combined with the effect of the background ambient wind, the vertical transmission routes will change as the relative forces of buoyancy and wind variation.

PURPOSE

- To explore the impact of solar radiation on near wall flow in a high-rise building.
- To investigated the combined effects of wind and buoyancy forces on pollutant transmission.
- To compare the differences of inter-flat transmission characteristics between sunward and shady side.

METHODS

Solar radiation intensity



The solar radiation intensity in each direction April 21st, Shanghai (S-South, N-North, E-East, W-West, H-Horizontal)

Suppose it's a sunny day, the atmospheric transparency is set as 0.62. At noon, during 11:00 to 13:00, the absolute sunward side is south and the solar radiation intensity is in the range of 410-440 W/m^2, while that of the opposite side is about 165 W/m^2. The received solar radiation intensity are in a very small range, which could be seen as a steady-state condition for the following calculation.

Temperature of wall surface

For outer wall surface

$$Q_{solar} = Q_{conduc} + Q_{convec} + Q_{lw}$$

$$Q_{solar} = \alpha I_{SV}$$

$$Q_{conduc} = \frac{T_{wout} - T_{win}}{\frac{\delta}{\lambda}}$$

$$Q_{convec} = h_{out}(T_{wout} - T_{aout})$$

$$Q_{lw} = \sigma \varepsilon_w x_{sky}(T_{wout}^4 - T_{sky}^4)$$

$$T_{sky} = 0.0552 T_{aout}^{1.5}$$

For inner wall surface

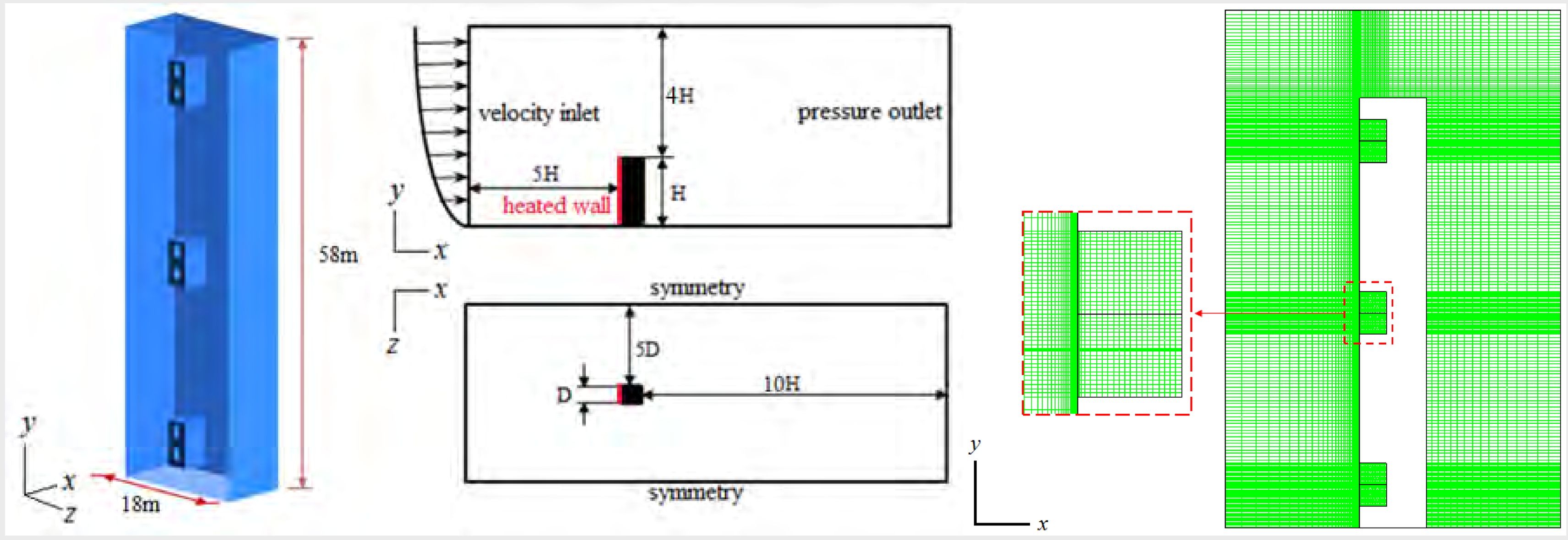
$$Q_{conducin} = Q_{convecin}$$

$$Q_{convecin} = h_{in}(T_{win} - T_{ain})$$

Relative parameters		
Time		Noon
Outdoor air temperature (K)		288.15
Sky effective temperature (K)		270
Solar radiation intensity (W/m²)	Sunward	430
	Night side	165
Wall surface temperature (K)	Sunward	301.16
	Night side	291.67

For an isolated building in a relative open terrain, suppose the temperature distribution on the outer wall surface is uniform, that is no vertical and horizontal temperature difference. The temperature of the sunward outer surface is 10K higher than the night side, and 13K higher than the outdoor air temperature.

Simulation configuration

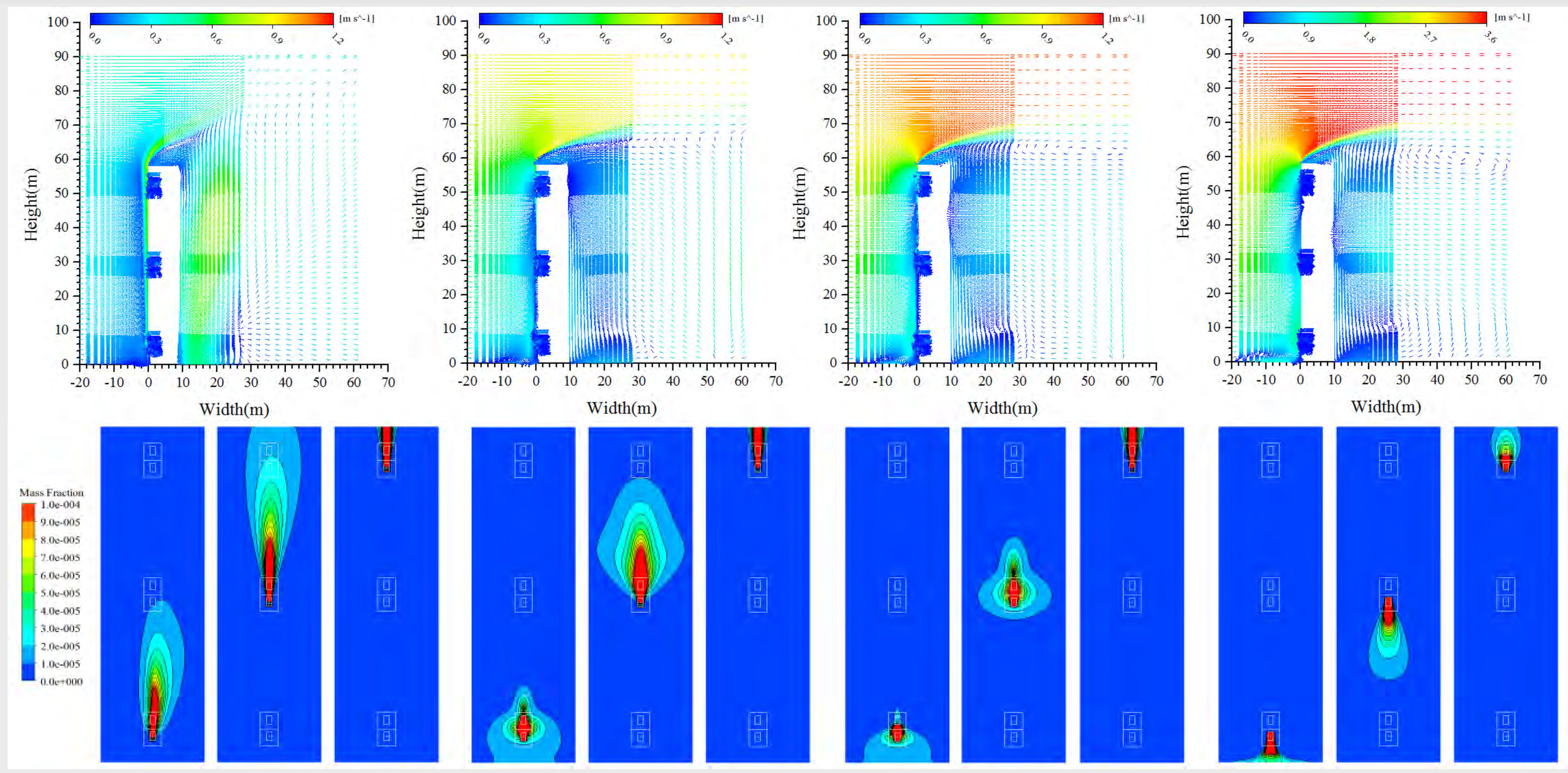


$$\frac{U(h)}{U_{ref}} = \left(\frac{h}{H_b}\right)^{0.22} \qquad Ri = \frac{Gr}{Re^2} = \frac{\beta \Delta T g H_b^3 / \nu^2}{(U H_b / \nu)^2}$$

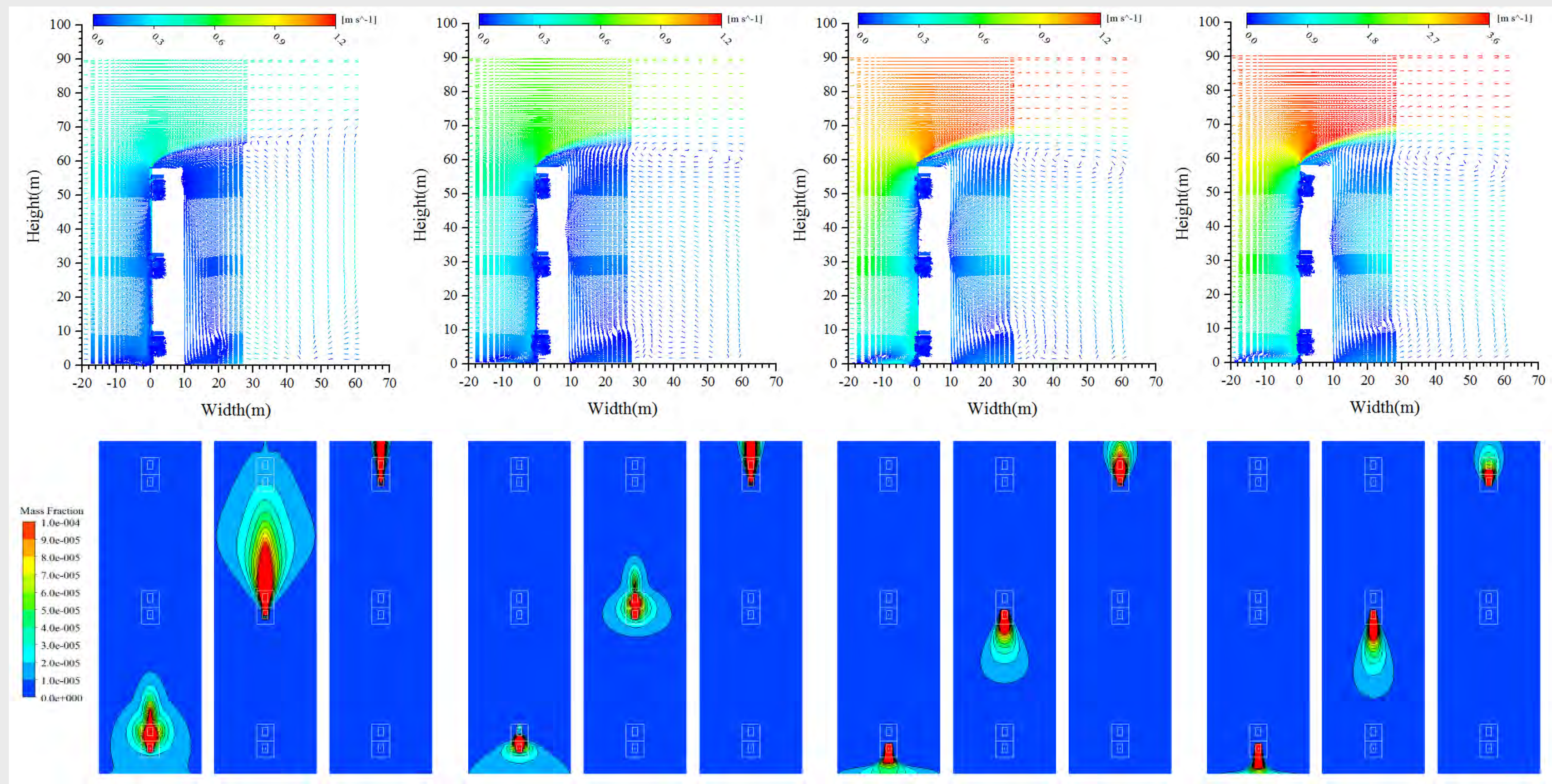
Case configuration

Case No.	Case Name	U_{ref} (m/s)	ΔT (°C)	Re	Gr	Ri
N1	O-ΔT13-U0.4	0.4	13	1.568×10^6	3.855×10^{14}	156.9
N2	O-ΔT13-U0.8	0.8	13	3.135×10^6	3.855×10^{14}	39.2
N3	O-ΔT13-U1.0	1.0	13	3.921×10^6	3.855×10^{14}	25.1
N4	O-ΔT13-U3.2	3.2	13	1.254×10^7	3.855×10^{14}	2.5
N5	O-ΔT3.5-U0.4	0.4	3.5	1.568×10^6	1.055×10^{14}	42.9
N6	O-ΔT3.5-U0.6	0.6	3.5	2.352×10^6	1.055×10^{14}	19.1
N7	O-ΔT3.5-U1.0	1.0	3.5	3.921×10^6	1.055×10^{14}	6.9
N8	O-ΔT3.5-U3.2	3.2	3.5	1.254×10^7	1.055×10^{14}	0.67

DISCUSSION



(N1) O-ΔT13-U0.4 (N2) O-ΔT13-U0.8 (N3) O-ΔT13-U1.0 (N4) O-ΔT13-U3.2



(N5) O-ΔT3.5-U0.4 (N6) O-ΔT3.5-U0.6 (N7) O-ΔT3.5-U1.0 (N8) O-ΔT3.5-U3.2

CONCLUSION

- The near wall thermal plume speed at the building height is up to 1.2m/s with a wall/ambient temperature difference of 13K.
- When the source location is below the stagnation zone, as the *Ri* number decreases, the effect of force convection strengthen, so the pollutant spread from lower floor to upper ones is weaken.
- When the source location is the 2nd floor, the vertical transmission is suppressed once *Ri* is below 40. When the source is released from the 10th floor, the vertical transmission is restrained once *Ri* is below 20.

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