UPWARD AND SIDEWARD REMOVAL OF AIR POLLUTANTS IN THREE-DIMENSIONAL STREET CANYONS

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Abstract

is project focused on the pollutant transport in idealized three-dimensional (3D) street nyons using computational fluid dynamics (CFD). A series of sensitivity tests were rformed to examine the effects of building-width-to-street-width ratio (WR) on the llutant removal behaviours. The results reveal the pollutant dispersion characteristics in) building configuration, and how WR affects the upward and sideward pollutant removal. sed on the current findings, it is suggested that the CFD results for idealized 2D street nyons should be interpreted with caution.

Methodology

CFD code: OpenFOAM-1.6

Turbulence Model:

Unsteady Reynolds-averaged Navier-Stokes
Renormalization group k-ε turbulence model

Parameters for the Street Canyon:

Building length in x direction: w (1m, 2m)
Building length in y direction: a (1m)
Building height: h (1m)
Street width in x direction: b (1m)
Building-width-to-street-width ratio (WR): w/b
Domain height: 8×h
Number of buildings in x direction: 8
Number of buildings in y direction: 5

Parameters for the Flows:

Characteristic length: h (1m);
Characteristic velocity: U_H(0.15m/s);
Reynolds number: $U_H \times h/\nu = 1.5 \times 10^4$
Number of grid points: about 10 million

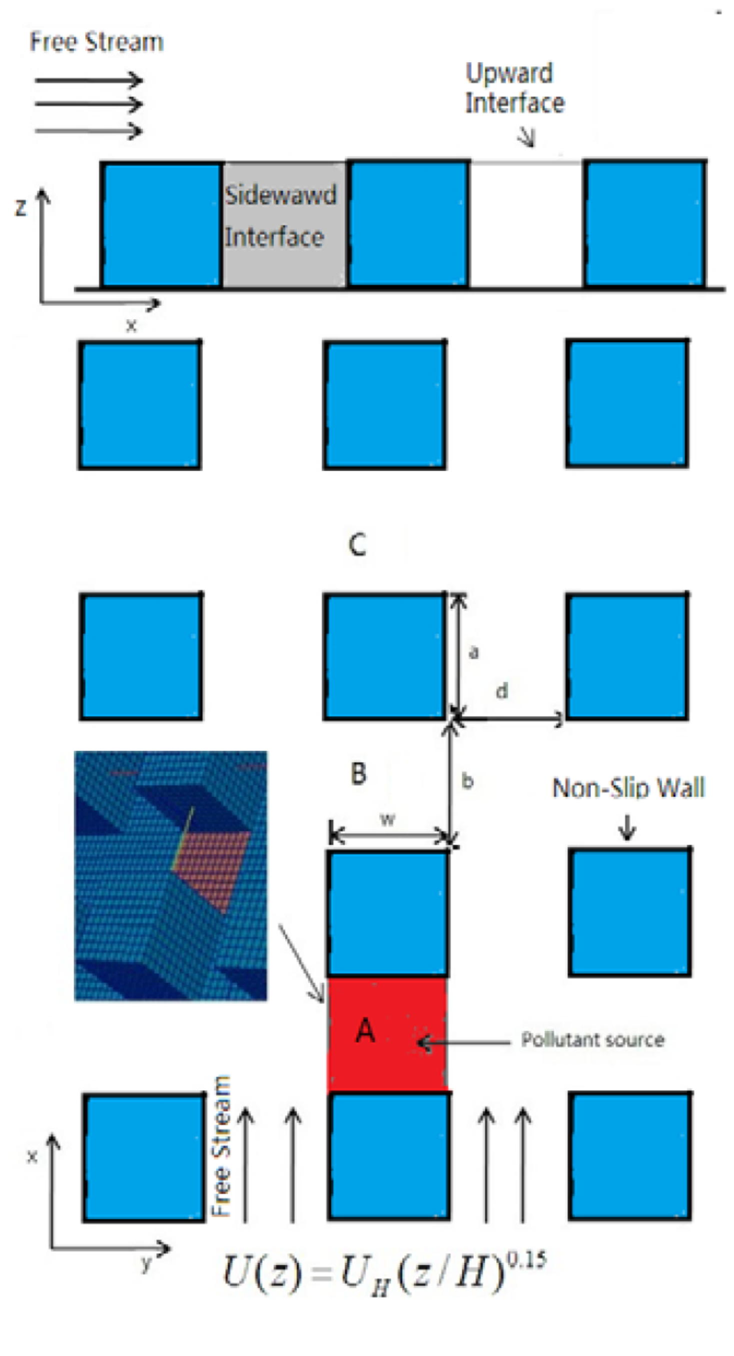


Fig 1 Computational domain

Parameters for the Pollutant Transport:

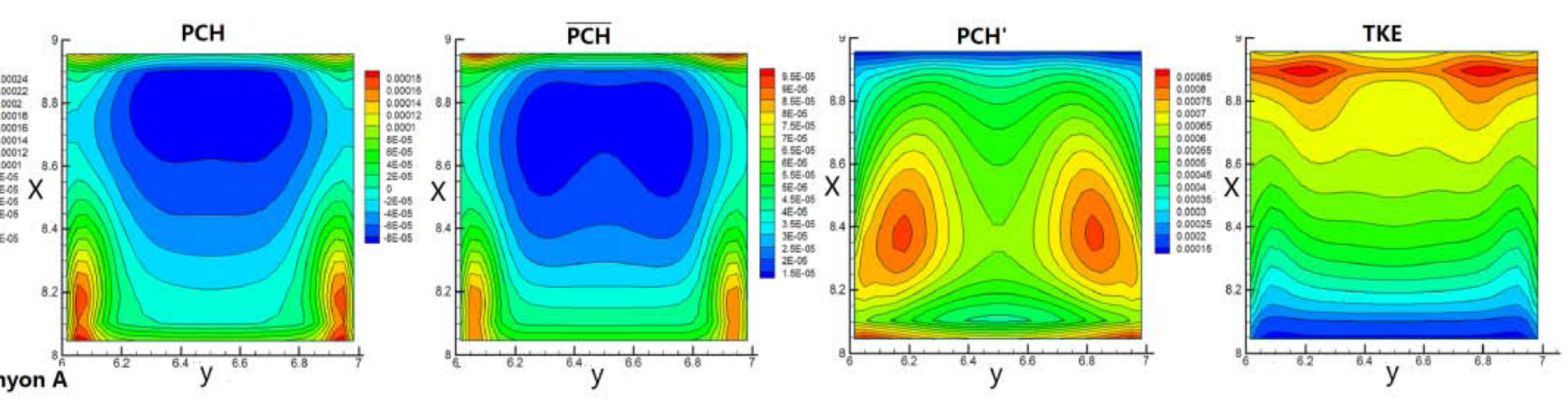
Pollutant concentration: c
Average pollutant concentration inside the canyon: $\langle c \rangle$
Pollutant exchange rate through an interface of area A: PCH
The total PCH is divided into two components:

$$\overline{PCH} = \int_A \overline{u_n}\,\bar{c}\,dA \qquad PCH' = -\int_A D_t \frac{\partial \bar{c}}{\partial n}\,dA$$

u_n is the velocity normal to the interface, D_t is the turbulent pollutant diffusivity.
The mean part $\overline{PCH}$ represents the pollutant transport by mean flow: The fluctuating part PCH' represents the pollutant transported by turbulence.

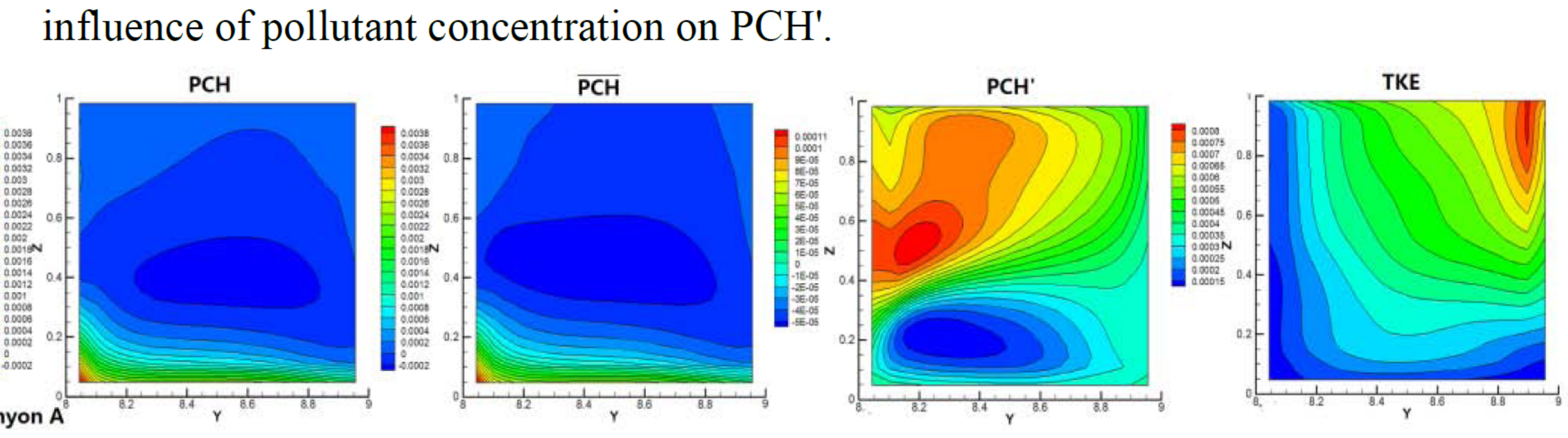
Results and Discussions

WR=1



2 Contours on the upward interface of Canyon A of WR=1

The contours of PCH and $\overline{PCH}$ exhibit similar patterns, implying the dominance of $\overline{PCH}$ in the pollutant entrainment (most contours are negative).
On the other hand, PCH' is positive (upward transport) and large, dominating the pollutant removal from the street canyon.
PCH' is the correlation between the vertical velocity fluctuation and pollutant concentration. The peaks of PCH' and TKE locate differently, signifying the strong influence of pollutant concentration on PCH'.



3 Contours on the sideward interface of Canyon A of WR=1

The dominance of pollutant removal (positive contours) through the sideward interface near the ground level is a result of the street-level area pollutant source.
Though TKE is peaked at the windward roof level, pollutant accumulates near the leeward building leading to the elevated PCH'.

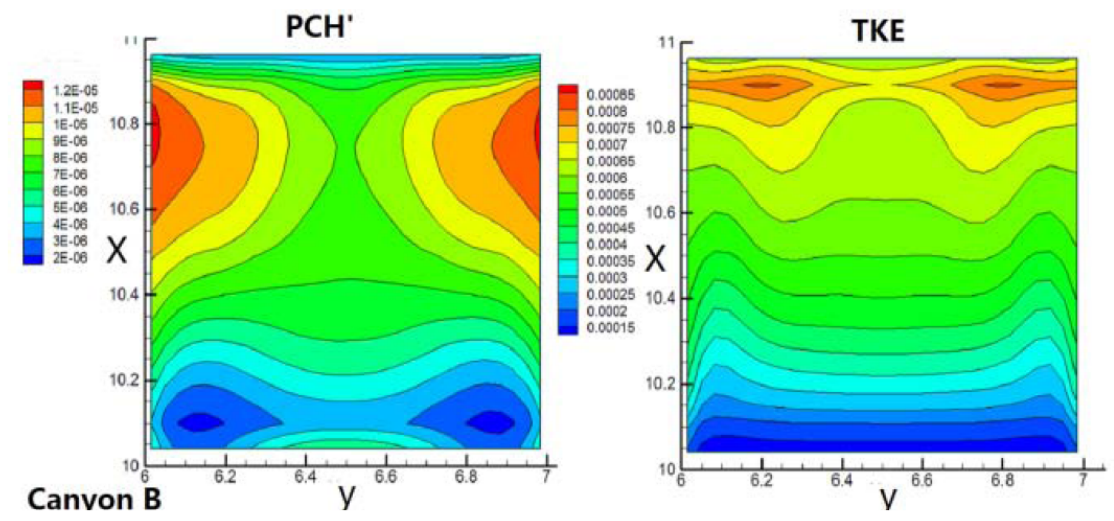


Fig 4 Contours on the upward interface of Canyon B of WR=1

The peaks of PCH' and TKE locat closely to each other on th sideward interface, signifying th stronger influence of turbulence o PCH'.

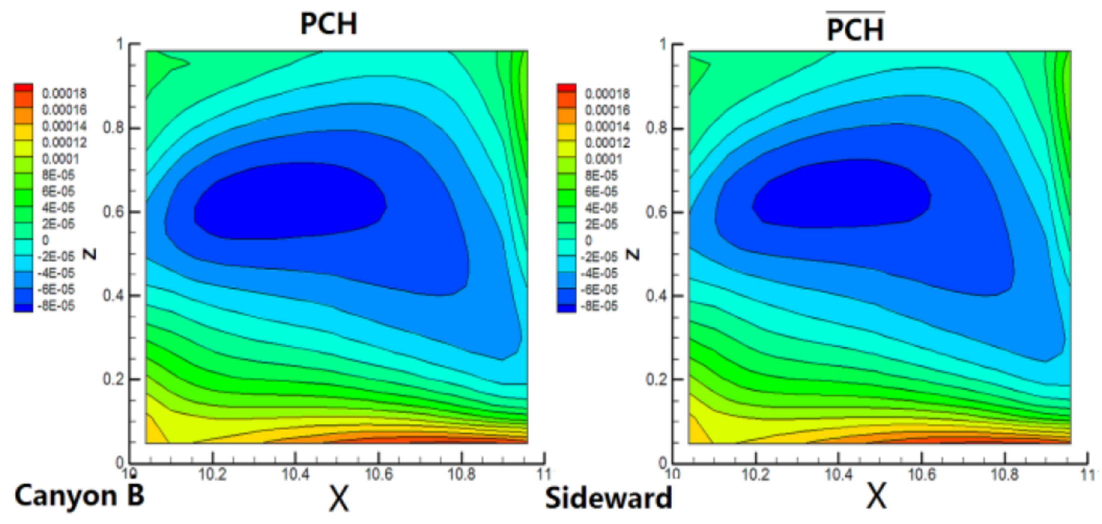


Fig 5 Contours on the sideward interface of Canyon B of WR=1

The pollutant from Canyon A i carried to the sideward interfaces o Canyon B. It enters into Canyon I following the mean flow (negativ contours), recirculation inside th street canyon and is finally removed from Canyon B through the upward interface b turbulence (positive contours in Fig 4).

WR =2

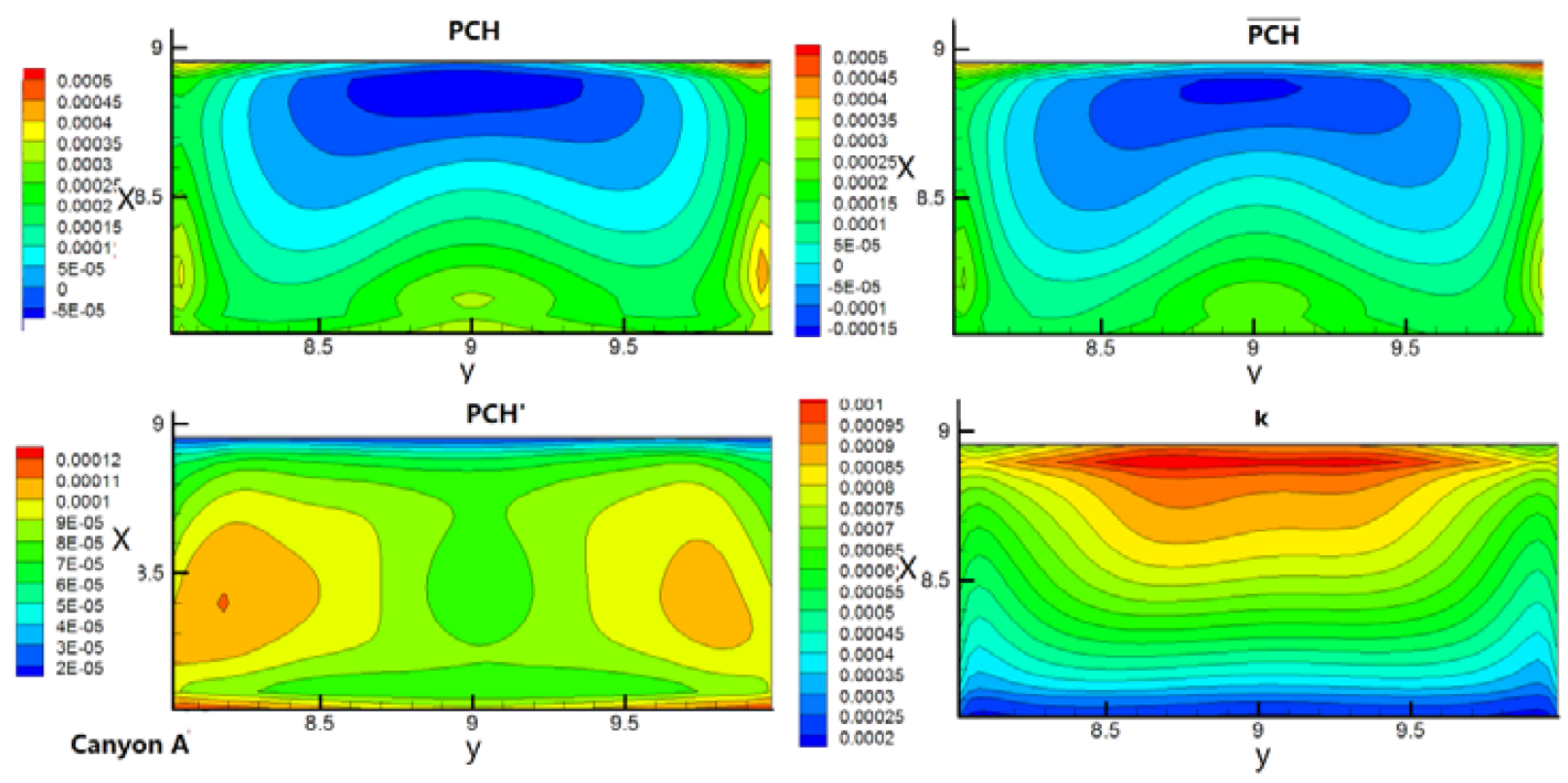
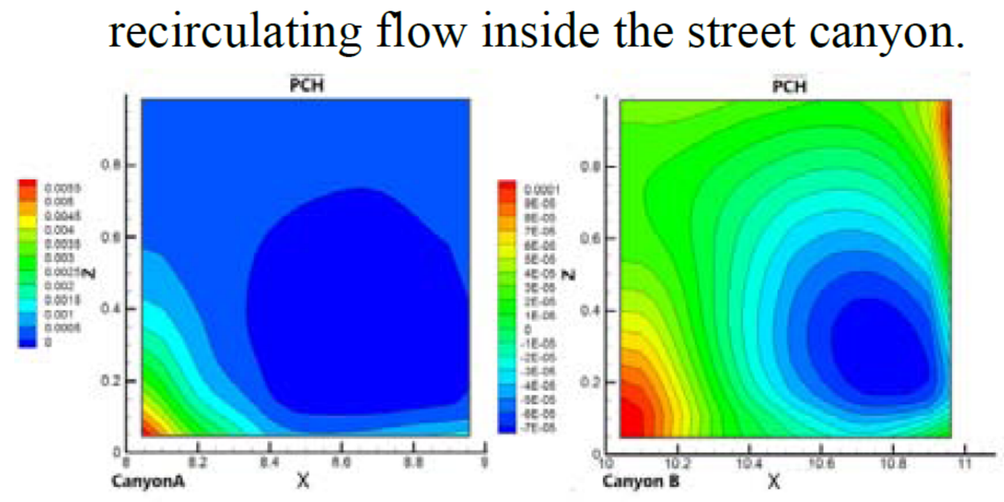


Fig 6 Contours on the upward interface of Canyon A of WR=2

1. Unlike WR = 1, the average $\overline{PCH}$ on the upward interface is positive, demonstrating th importance of mean flow in pollutant removal from a wider street canyon.
2. Similar to WR = 1, the pollutant removal on the upward interface by PCH' (positiv contours) peak near the sides of the street canyon which is likely the result of th recirculating flow inside the street canyon.



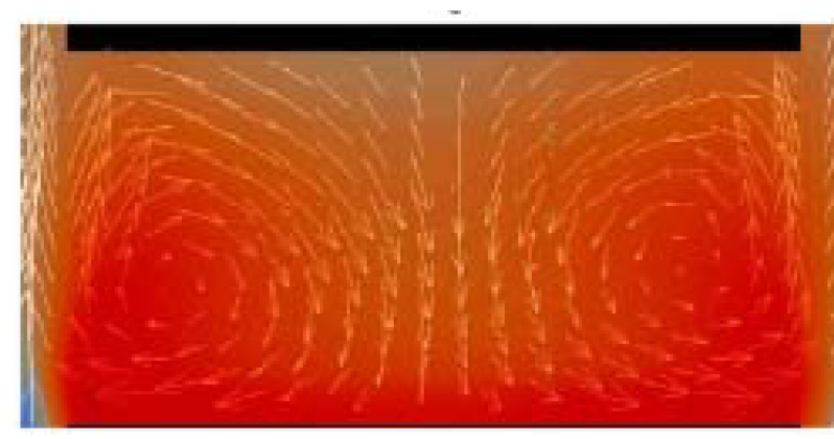


Fig7 Contours on the sideward interface of Canyon A&B of WR=2 Fig8 Vector profile sampled in h=0.5 for WR=2

Compare Fig 3, 5, 7, the pollutant removal in WR = 1 is distributed evenly at the groun level while in WR = 2 is shifted toward the leeward ground level. These dissimilar pollutar transport behaviours are caused by the recirculation of different nature (Fig 8).

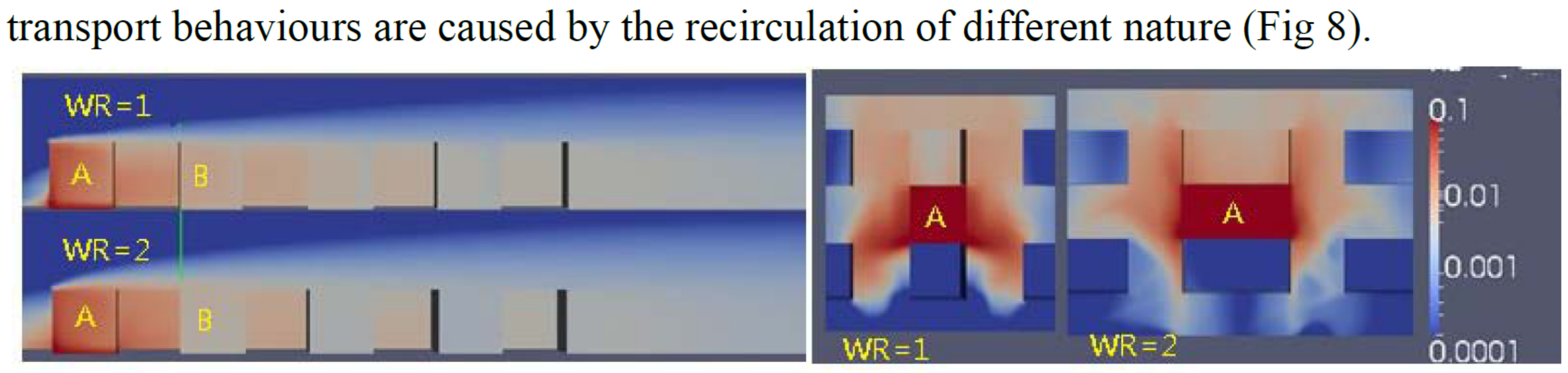


Fig 9 Pollutant concentration contours

In fact the pollutant could be transported opposite to the free-stream flow that goes int upstream along the street below the roof level. This re-entrainment mainly takes plac through the sideward interfaces that is less significant in street canyons of larger WRs.

Conclusions

1. Generally, pollutant entrainment is dominated by mean flow while pollutant removal i dominated by turbulence.
2. When WR is increased from 1 to 2, the wider canyon enhances the performance of $\overline{PCH}$ while PCH' remains the same pattern. Hence, PCH is improved.
3. In the roof level of Canyon A, the contribution of PCH' is mainly attributed to th peaks near the sideward interfaces. When the street is widened, these peaks affect les within a smaller region, the overall PCH' performance is weakened.
4. Pollutant could be carried into the upstream canyons which is a process governed by th sideward pollutant removal and entrainment

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