Atmospheric Dispersion within Obstacle Arrays: Modelling of Mean Concentration and Concentration Fluctuations

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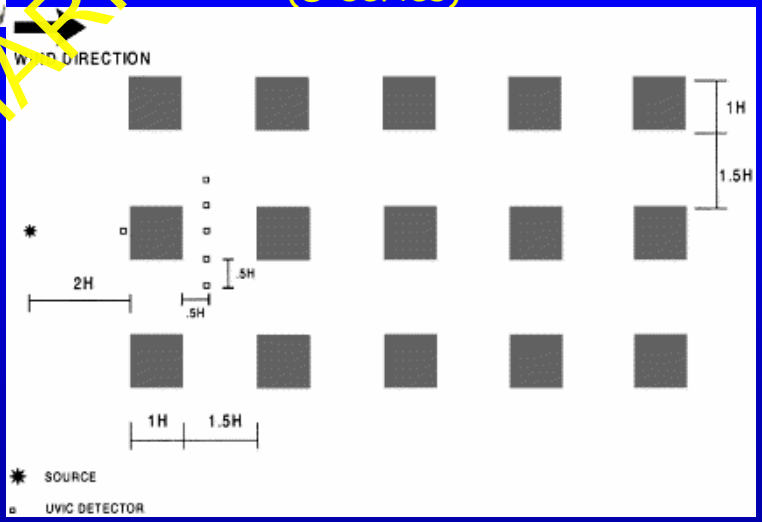
Experimental Set-up: "In-line array", (S-series)

Cubical model-buildings H = 1.15 m

Pollutant: C_3H_6

Flow rate: 2.49×10^{-4} m^3/s

Released Horizontally at height H/2, continuously



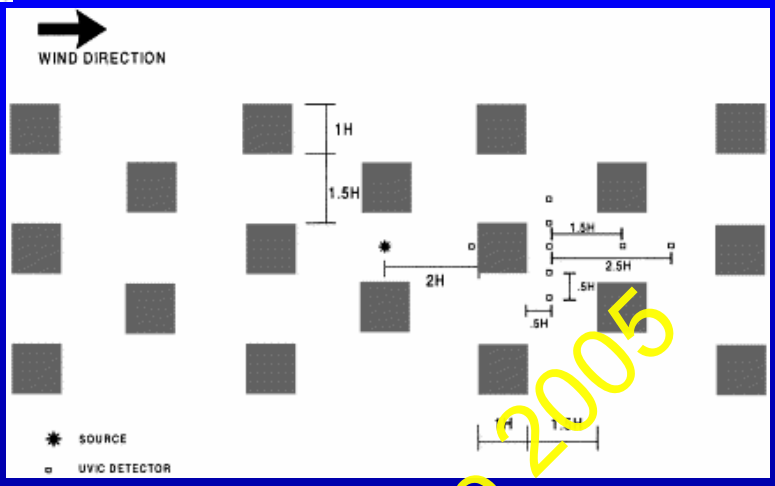
Experimental set-up: "Staggered array" (T-series)

Cubical model-buildings H = 1.15 m

Pollutant: C_3H_6

Flow rate: 2.49×10^{-4} m^3/s

Released Horizontally at height H/2, continuously



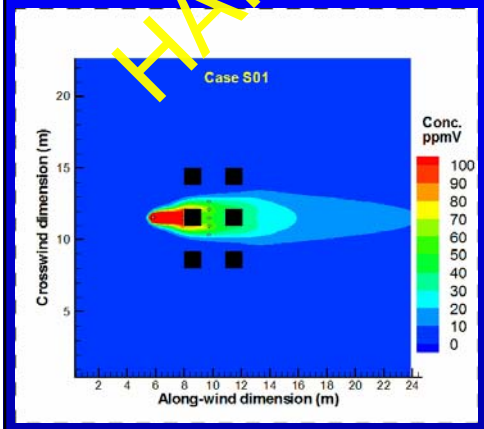
Simulated experimental cases

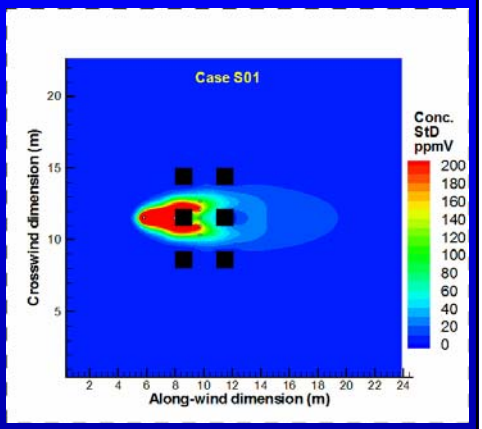
Case code / array configuration	Source location relative to centre-line
S01 / in-line	0.0 H
S02 / in-line	0.5 H
S03 / in-line	1.0 H
S04 / in-line	1.5 H
S05 / in-line	2.0 H
T05 / staggered	0.0 H
T06 / staggered	0.25 H
T07 / staggered	0.5 H
T08 / staggered	0.75 H

Computational tool

- CFD code ADREA-HF
  - Finite volumes
  - Reynolds-averaged equations
    - Mixture (air/pollutant) mass
    - Momentum
    - Pollutant mass fraction
    - Pollutant mass fraction variance
  - Turbulence closure:
    - Eddy viscosity/diffusivity, *k*-/ or *k*-ε model (standard)
  - Computational grid:
    - S-series: 90 x 86 x 30 cells
    - T-series: 153 x 68 x 30 cells
    - Variable grid, minimum cell dimension: 0.144 m

Results: Horizontal contours at source height





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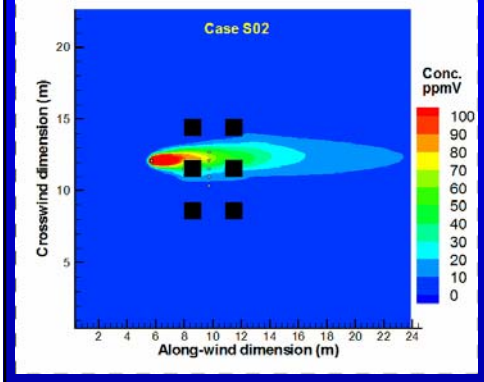

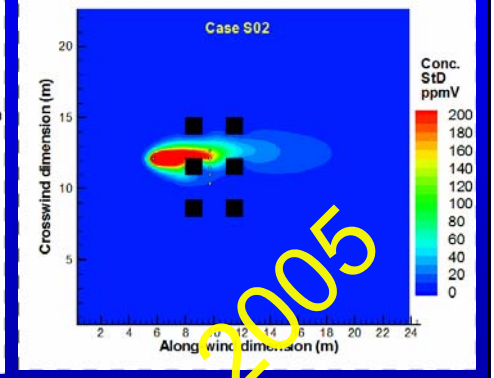

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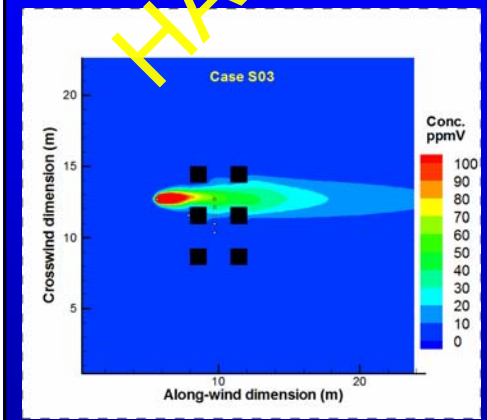

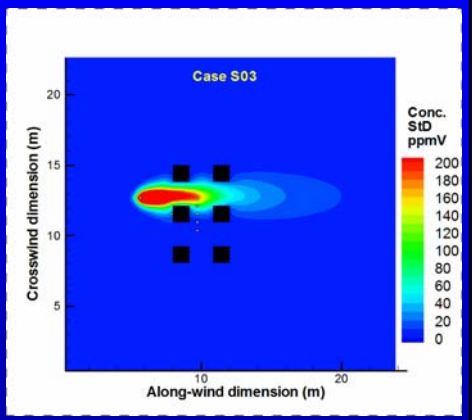

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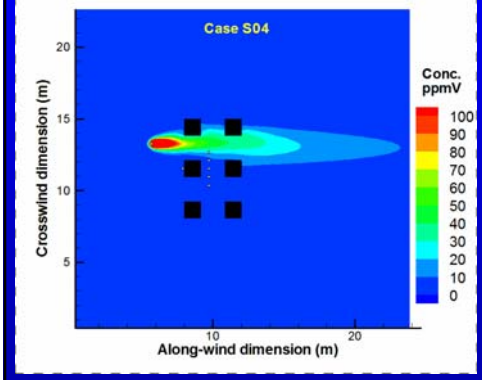

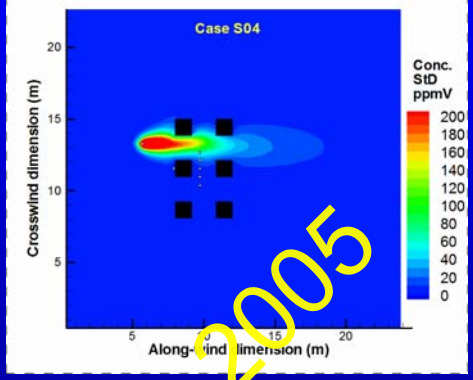

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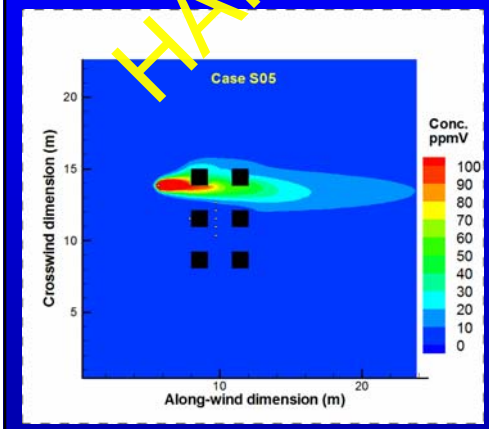

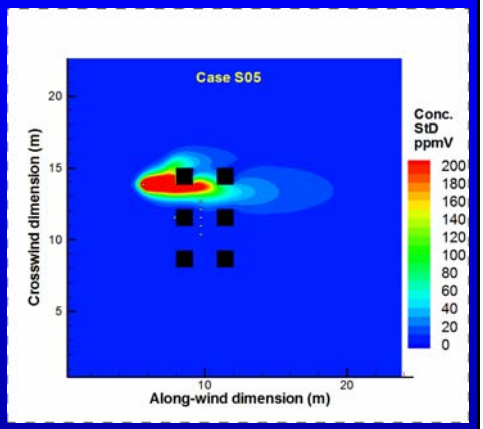

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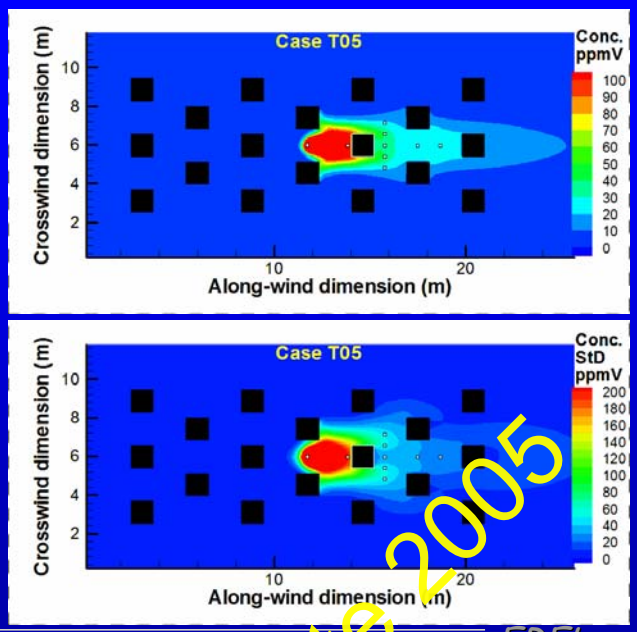

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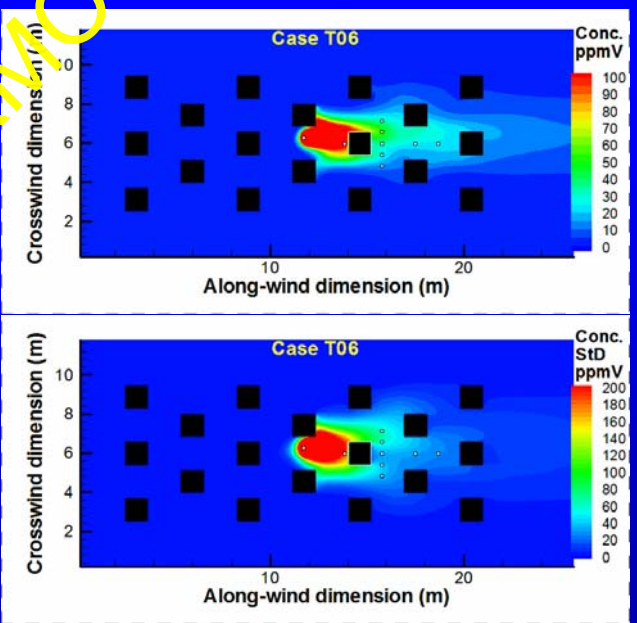

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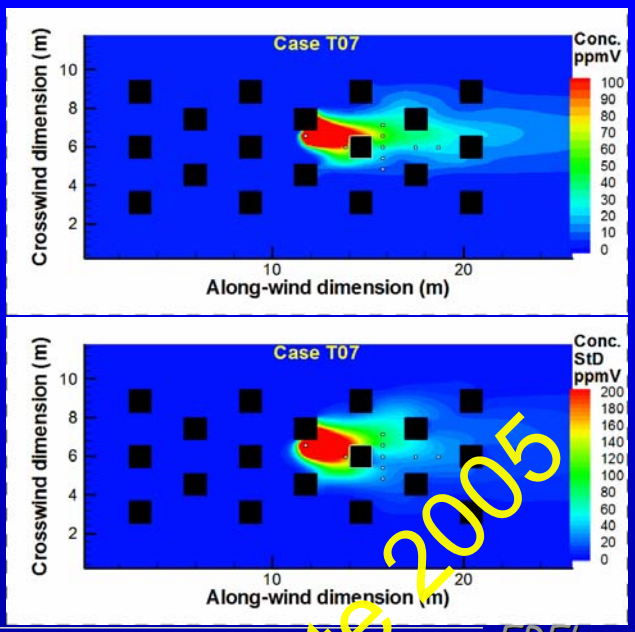

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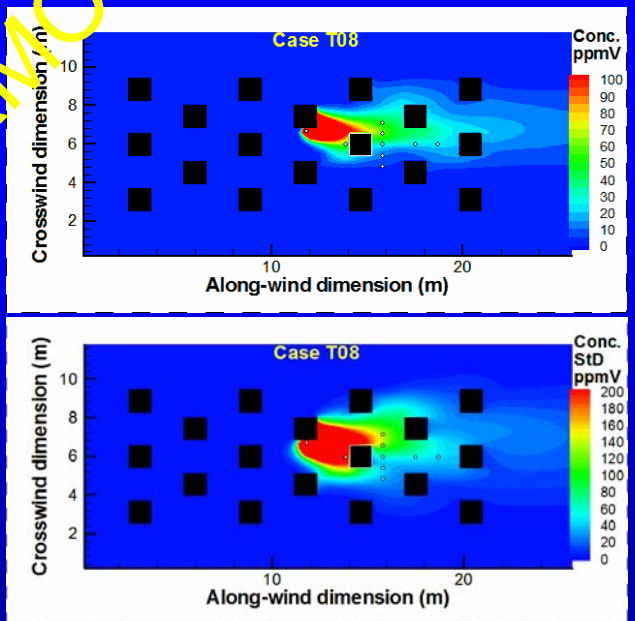
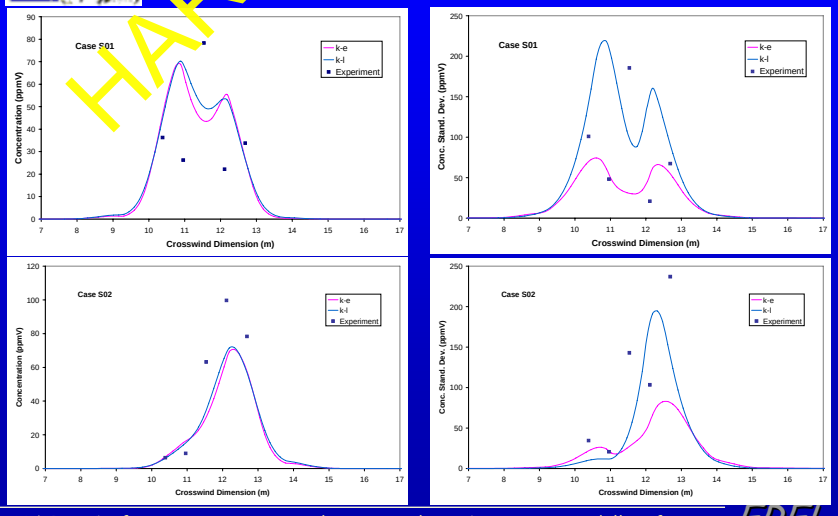


Discussion

- Plume bifurcation in symmetric cases
- When the gas source is located inside the staggered array, the plume is entrained in the wakes of the buildings located laterally and upwind the source

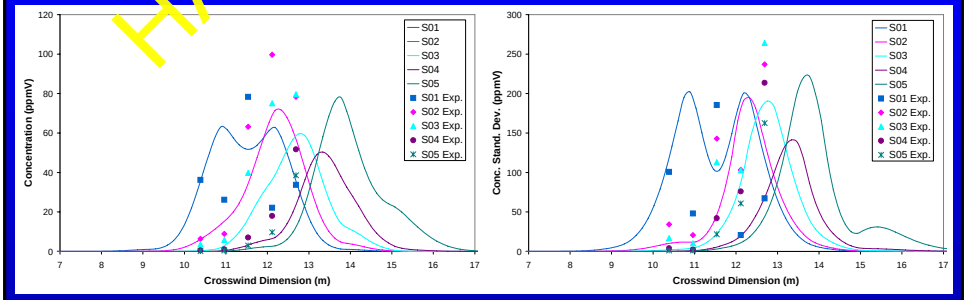
Sensitivity tests: effect of turbulence closure



Discussion

- The effect of the choice of turbulence model (k-l or k-ε) on the mean concentrations was small, while the effect on concentration standard deviations was more significant
- The k-ε model gives in general smaller values of the concentration standard deviation, indicating higher dissipation rates
- Characteristic cloud bifurcation in the cases with the source located on the building centreline (S01, S05) - apparent from contour plots and crosswind profiles

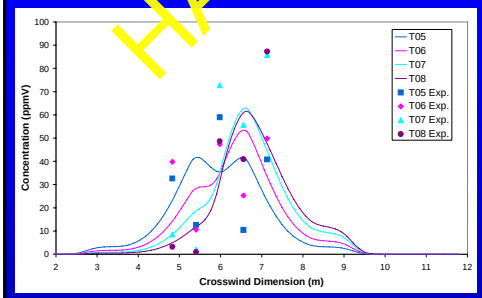
Crosswind profiles for S-series (in-line buildings array)

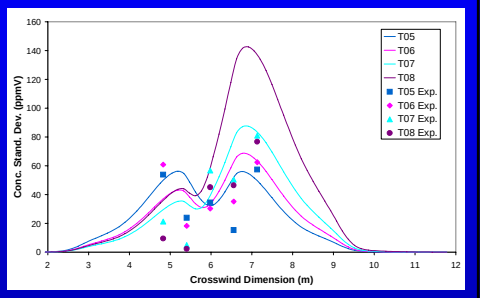


Discussion

- Crosswind profiles / in-line array:
  - The experimental data for case S01 (symmetric case) present a maximum value at the central detector which is not captured by the model
  - The plume in the case of the laterally displaced source presents a single concentration maximum
  - The model results indicate that the highest concentration peaks occur for cases S02 and S05, where the source is aligned with a lateral side of an obstacle

Crosswind profiles for T-series (staggered buildings array)

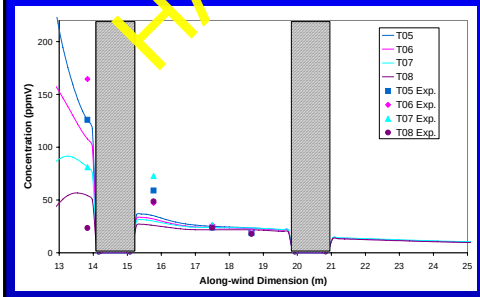


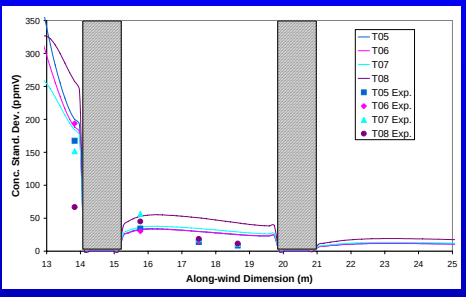


Discussion

- Crosswind profiles / staggered array:
  - Plume bifurcation for symmetric case (T05)
  - For cases T06 to T08, where the source is displaced laterally, the plume's single maximum is located at the same position (small displacement of the source, channeling of the plume between the buildings)
  - The maximum centreline concentration values are observed for cases T07 and T08, where the source is close to the lateral side of the obstacle

Along-wind profiles for T-series (staggered buildings array)

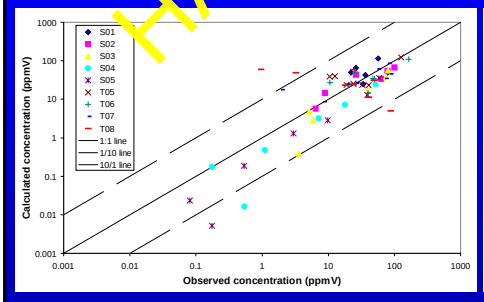


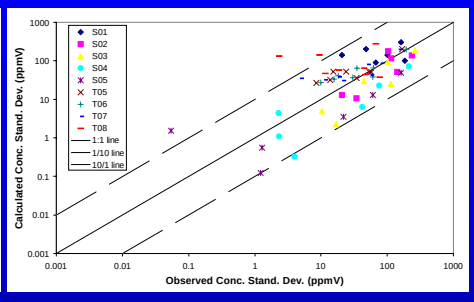


Discussion

- Along-wind profiles / staggered array:
  - The difference of concentrations observed at the upwind and downwind faces of the first building decreases as one moves from case T05 to T08 and the source is displaced laterally
  - The calculated profiles downwind of the buildings show very little variation in the along-wind direction as well as between the different experimental cases
  - The experimental concentrations vary more with the along-wind distance, indicating that the model possibly predicts a higher mixing rate than what is observed

Dispersion model evaluation





Discussion

- *Model evaluation, comparison with experimental data*:
  - mostly within a factor-of-10
  - better agreement for higher concentration values
  - discrepancies increase at lower concentration values for cases with the gas source is displaced from the obstacle centre-line.

Summary of Conclusions

- The results indicated a bifurcation of the plume when the gas source was positioned on the centreline
- In the case of a laterally displaced source, a single plume peak was observed, which had a maximum when the source was aligned with the lateral side of the obstacle
- The use of different turbulence closure schemes affected only the magnitude of the computed concentration fluctuations and not the mean concentrations
- Regarding the overall model performance, the majority of the model results lied within a factor-of-10 to the experimental data, while the agreement was much better at the higher range of concentrations