# Study on Urban Pollution Caused by Hazardous Substance Generation

#### Hazardous substance generation assumed in research

Leakage of combustible substances to cities due to accident, destabilization of social situation in recent years The terrorist attacks on biological weapons, chronic air pollution so far (urban transportation, factory Exhaust gas) becomes apparent.

Time history after concentration occurrence \_ Time taken to reach a remote place after the occurrence of hazardous substance generation



Variation in concentration

Statistical variation in concentration that changes from moment to moment

### **Concentration time history measurement (wind tunnel experiment)**



Left is the concentration of harmful substances when they occur suddenly Indicate the time history. The figure on the left shows one measurement. Concentration fluctuates greatly with time. Sometimes Is about five times as large as the average concentration (1.0 in the figure) There is time to take. The lower left is the average concentration It is a time history.



○Fig.5 Geometrical condition Source generation

 $\Rightarrow$  Wind tunnel experiment with transport of concentration including frequency distribution Validate by numerical analysis and take predictable measures.

○Fig.1 Air pollution by traffic incidents



Difference of danger /arrival time of pollutant /fluctuation of concentration

### **Frequency distribution** of concentration (wind tunnel experiment) $\rightarrow$

- The red graph shows the time history of concentration,
- The blue graph shows its
- frequency distribution
- (probability density distribution) Respectively.
- All figures are calculated by subtracting the average value
- and by standard deviation It is standardized.
- The average values are all equal. but the degree of dispersion of values
- The fit is greatly different for each condition



○Fig.2 Tokyo saline gas attack, 1995 (Jiji Press Ltd)



○Fig.6 Time history and Probability Density Function

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# Wind Tunnel Experiment vs Numerical Analysis (Large Eddy Simulation)

## High moment

Indicators used to infer the shape of the frequency distribution

 $\rightarrow$  Distortion degree (Skewness)

$$\frac{\mathrm{E}[(\theta-\mu)^3]}{\mathrm{E}[(\theta-\mu)^2]^{\frac{3}{2}}}$$

$$\mu = \int_{-\infty}^{\infty} \theta f(\theta) d\theta \qquad \mathrm{E}\left[\left(\theta - \mu\right)^n\right] = \int_{-\infty}^{\infty} \left(\theta - \mu\right)^n f(\theta) d\theta$$

# Q. Does numerical analysis have reproducibility of frequency distribution?

Comparison with wind tunnel experiment conducted under identical conditions

## **Calculation condition**

Standard smagorinsky model Orthogonal grid 12400000

(Nx,Ny,Nz)=(379,375,87)

**Boundary condition** 

inflow: dumped data outflow : advective outflow wall, ceiling : gradient 0 floor : no slip

SMAC pressure Time dev. Adams-Bashforth Descritization 2<sup>nd</sup> order central (around the source) QUICK

Although there is an overestimation of the average concentration, The overall trend of statistics on concentration fluctuations is Match.

Here, numerical analysis by LES is based on analysis of density field I judge that it is enough.







○Fig.9 Comparison with experiment

○Fig.7 Indicator of P.D.F's distortion



○Fig.8 LES of pollutant dispersion







**Fluctuation Intensity** 

Skewness

○Fig.10 Distributions stochastic properties





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# Frequency Distribution Shape by Numerical Analysis

### Verification of transportation balance by numerical analysis

Frequency distribution Verify transport of strain to obtain information that contributes to shape prediction. Focus on transport equation of quantity included in distortion degree

diffusion

Distribution of concentration

transport



## Central moment of order n

transport



$$\frac{\partial \langle c'^{3} \rangle}{\partial t} = -\langle u_{j} \rangle \frac{\partial \langle c'^{3} \rangle}{\partial x_{j}} - \frac{\partial \langle u'_{j} c'^{3} \rangle}{\partial x_{j}} - 3 \langle c'^{2} u'_{j} \rangle \frac{\partial \langle c \rangle}{\partial x_{j}} + 3 \langle c'^{2} \rangle \frac{\partial}{\partial x_{j}} \langle u'_{j} c' \rangle + 3 \langle c'^{2} \frac{\partial}{\partial x_{j}} \left( \Gamma \frac{\partial c'}{\partial x_{j}} \right) \rangle$$

Consider the possibility of approximate calculation of terms of lower order.





tb:turbulent diffusion cv:convection pr:production ds 2:dissipation +numerical diffusion rs\_2:residual

tb\_3:turbulent diffusion cv\_3:convection pr\_3:production? un 3:unknown ds 3:dissipation? rs3:residual

 $\bigcirc$  Fig.12 Production and Dissipation of n=2

 $\bigcirc$  Fig.11 Budget of n=2,3

 $\bigcirc$  Fig.13 Production(?) and Dissipation(?) of n=3

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# **Future Tasks**

Currently the cost of computing is too high to do LES, so for incidents and accidents It is not realistic to calculate in advance.

additionally

If you can calculate it, you can contribute to grasping the danger in case of emergency.

### Approximate evaluation (Channel flow)

A. Gradient diffusion approximation similar to high order correlation term of k - e model



B. Time scale ratio R '









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