Validation of a numerical simulation system for gas diffusion in an Urban Area

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Research Consortium of MEXT project

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Project leader: Prof. Shinsuke Kato

Main organization : Tokyo university

Subtheme-1 : Ryohji Ohba (MHI)

- Development of an advanced prediction system for atmospheric diffusion

Subtheme-2 : Masatoshi Nihei(AdvanceSoft)

- Development of a practical prediction system for diffusion in enclosed space

Subtheme-3 : Shinsuke Kato (Tokyo university)

*Verification test for the prediction system for atmospheric diffusion

Related project : Development of an identification method for contaminant source

Subtheme-4 : Tomohisa Yamashita (AIST)

- Development of an evacuation assist system

Cooperaing organizations : Tokyo Metropolis, NPO et al.

Project schedule

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Sub theme	2007	2008	2009
1) Prediction system for atmospheric diffusion	High-speed computing system	Validation of the system with field experimental data	Evaluation of total system with emergency response drill by Tokyo Metropolis
2) Prediction system for diffusion in an enclosed space	Base system, Add sub-models	Make-up and Validation of the system	
3) Verification Test	Wind Tunnel Experiment	Full-Scale Experiment	
4) Development of an evacuation assist system	Development of the integrated system	Validation of the evacuation assist system	
Annual target	Development of fundamental technology	Validation of each technology	Evaluation of the total system

Hazardous gas dispersion simulator

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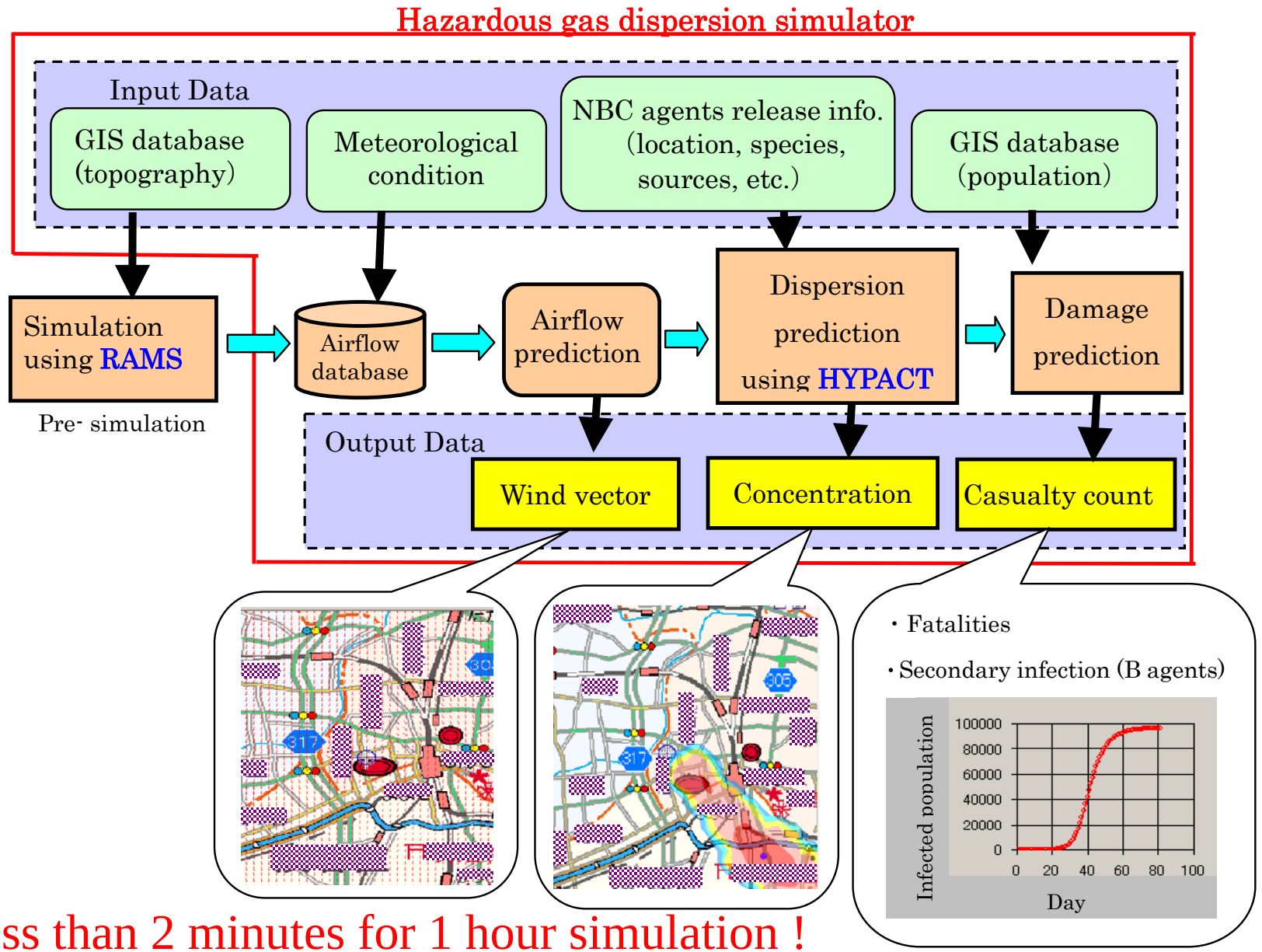

Less than 2 minutes for 1 hour simulation !

Database Computing Scheme for Air Flow

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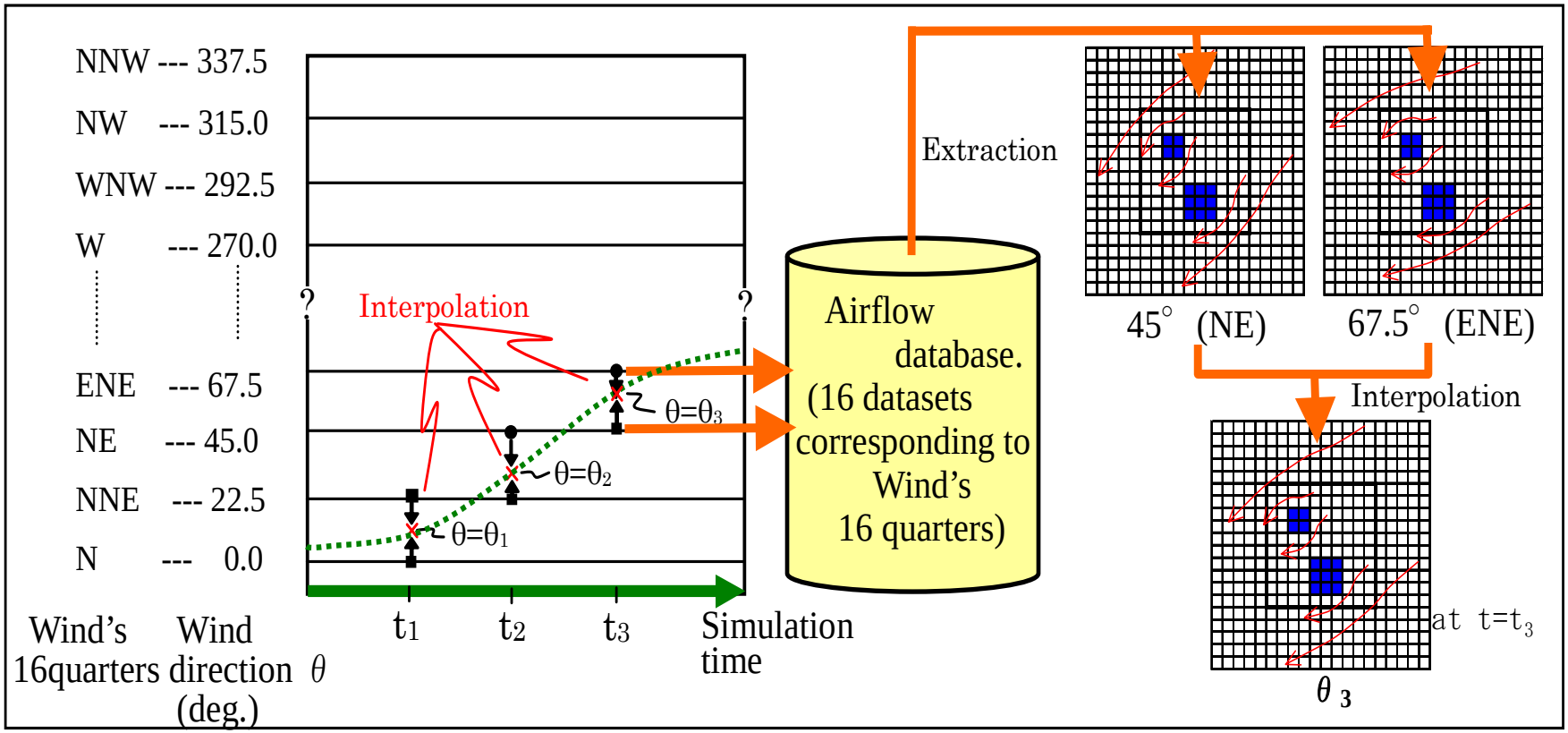

Model	100 m <	100 m >	Total
Present model	Few min.	Few sec	Few min.
Conventional	10 min.	200 min.	Few hrs

Comparison of wind speed profile

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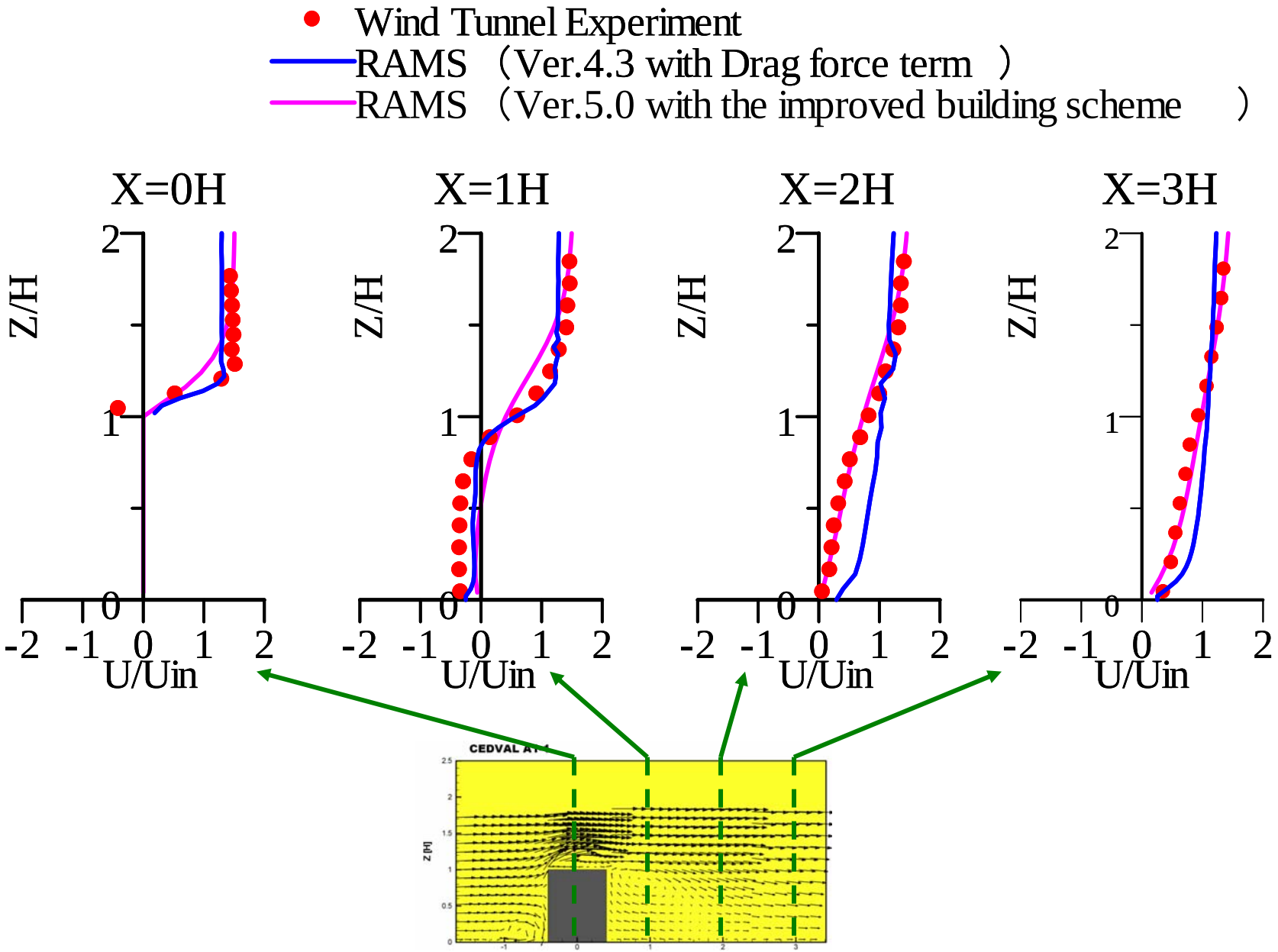

Evaluation of wind field by VDI

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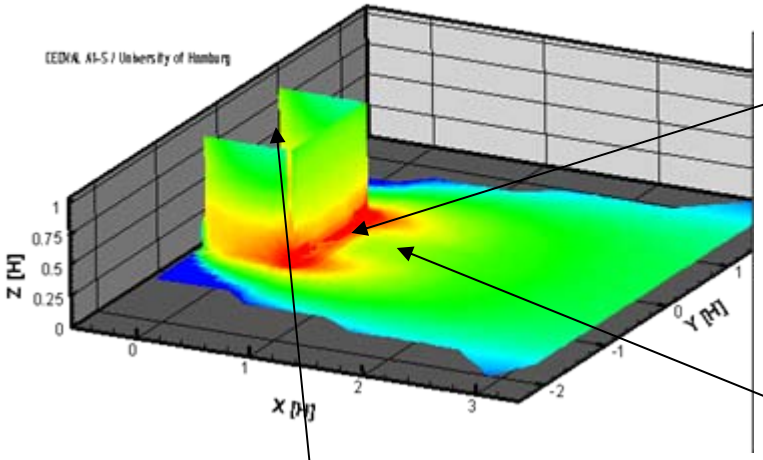
		Hit-rate q (%)		
	***x*/H**	***u*-component**	***w*-component**	**TKE**
Upstream	- 1.66	84.6	92.3	0.0
	- 1.18	92.3	92.3	16.7
above the obstacle	- 0.40	85.7	42.8	25.0
	- 0.24	71.4	42.8	14.3
	- 0.08	85.7	71.4	25.0
	+ 0.08	85.7	71.4	37.5
	+ 0.24	100.0	57.1	42.8
	+ 0.40	85.7	28.6	71.4
Downstream	+0.48	71.4	92.3	8.3
	+ 0.96	38.4	69.2	8.3
	+ 1.20	15.3	69.2	8.3
	+ 1.44	15.3	69.2	25.0
	+ 1.68	30.1	84.6	25.0
	+ 1.92	30.1	69.2	25.0
	+ 2.16	23.1	92.3	30.1

The German VDI Guideline (2005) fixed the minimum limit for validation at q > 66%

$$q(\%) = \frac{100}{n}\sum_{i=1}^{n} N_i \qquad N_i = \begin{cases} 1, \text{ if } \left|\frac{P_i - Obs_i}{Obs_i}\right| < RD \text{ and } \left|P_i - Obs_i\right| < AD \\ 0, \quad \text{else} \end{cases}$$

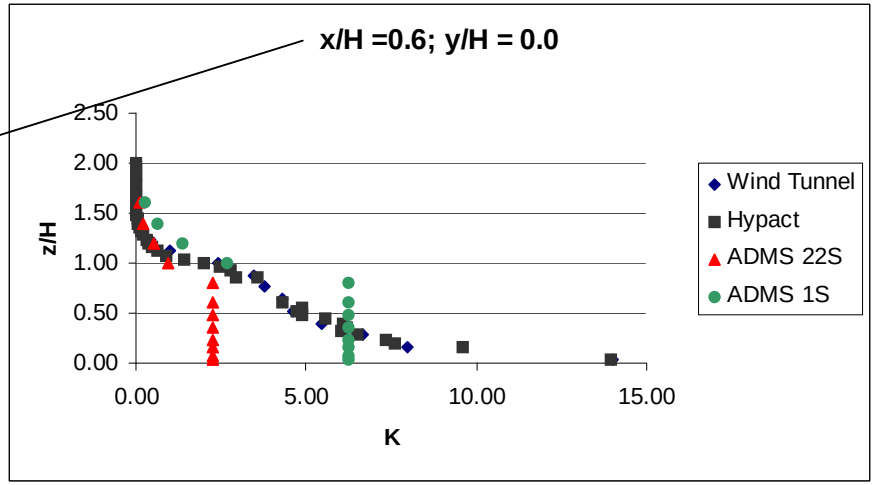
RD (relative discrepancy) = 0.25, and
AD (absolute discrepancy) = 0.05

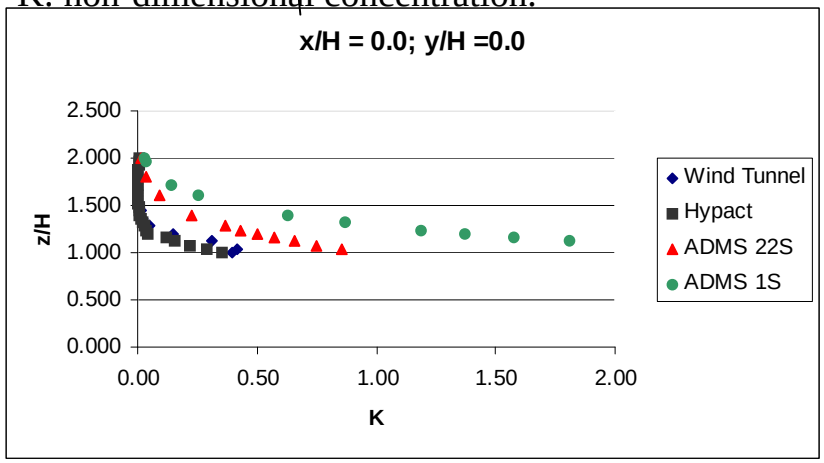
Comparison of gas concentration

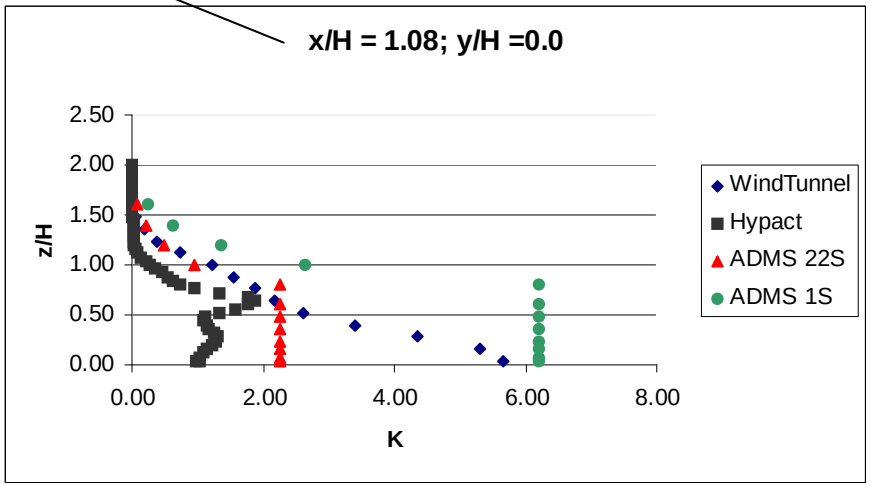


(from: http://www.mi.uni-hamburg.de/Category-A.628.0.html)

K: non-dimensional concentration.







Evaluation of gas concentration by EU/COST-732

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		K (HYPACT)		*K* (ADMS 1S)		*K* (ADMS 22S)	
		FAC2 (%)	**FB**	**FAC2 (%)**	**FB**	**FAC2 (%)**	**FB**
	***z*/H**						
***x*/H = 0.408**	0.12	100.0	-0.54	0.0	1.98	0.0	1.98
	0.20	100.0	-0.25	0.0	1.85	0.0	1.85
	0.52	100.0	-0.21	100.0	0.24	0.0	0.49
	1.0	100.0	-0.19	50.0	0.89	50.0	1.26
	x/H						
y/H = 0.0	0.00	71.4	0.61	0.0	-1.55	5.0	-1.85
	0.16	100.0	-0.08	0.0	-1.61	45.2	-1.80
	0.48	81.0	0.69	80.0	0.84	60.0	1.06
	0.60	81.3	0.30	63.3	-0.41	54.0	1.11
	0.72	75.0	0.14	100.0	-0.84	66.6	0.64
	1.08	85.7	0.30	41.6	-1.31	83.0	0.31
	0.00	71.4	0.61	0.0	-1.55	5.0	-1.85
	0.16	100.0	-0.08	0.0	-1.61	45.2	-1.80

FAC2 > 54% indicates a satisfactory model performance(COST-732)

Comparison of gas concentration in Tokyo

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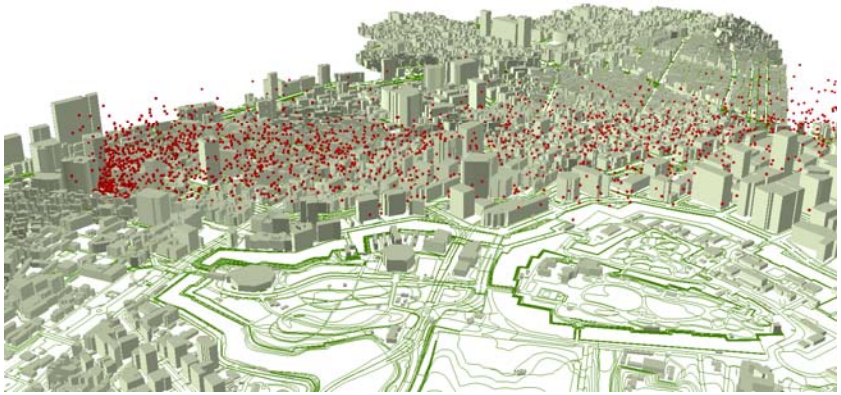
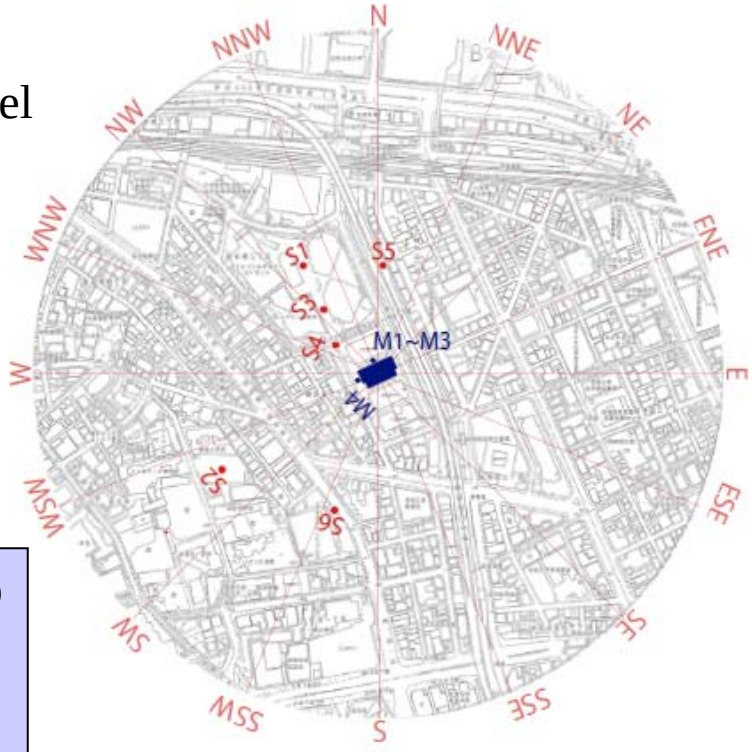
Particle distribution



Region of wind tunnel model

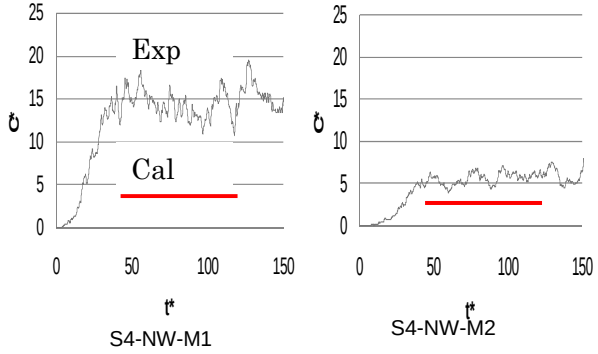


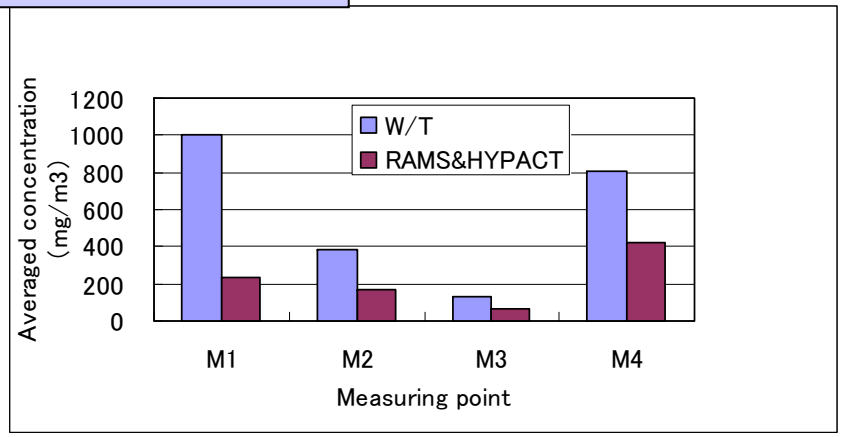
Wind direction: NW

Source position : S4

Underestimation seems to be due to the canopy effect of low buildings neglected by simulation.

a) Point M1 b) Point M2





Animation movie of numerical simulation

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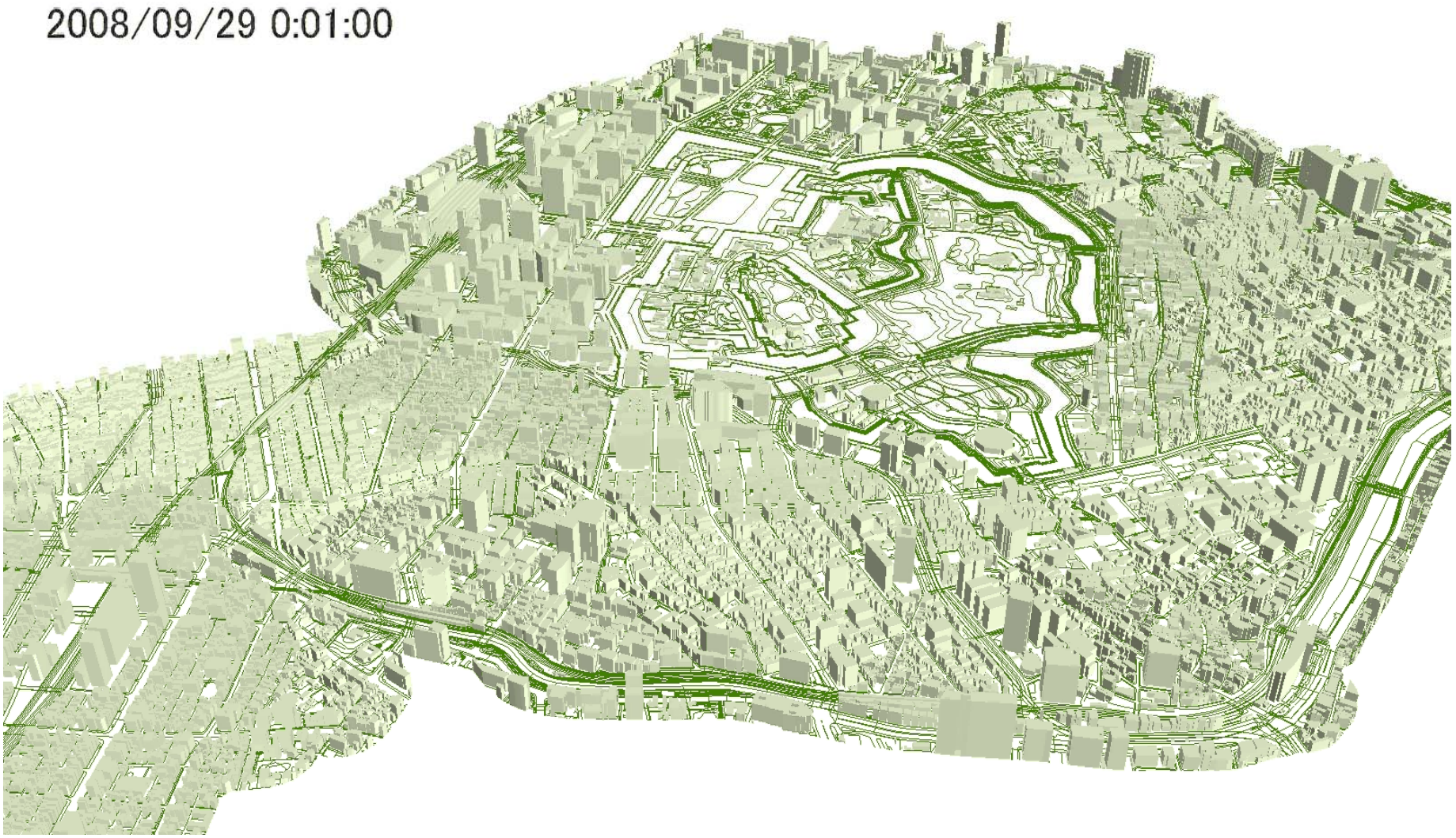
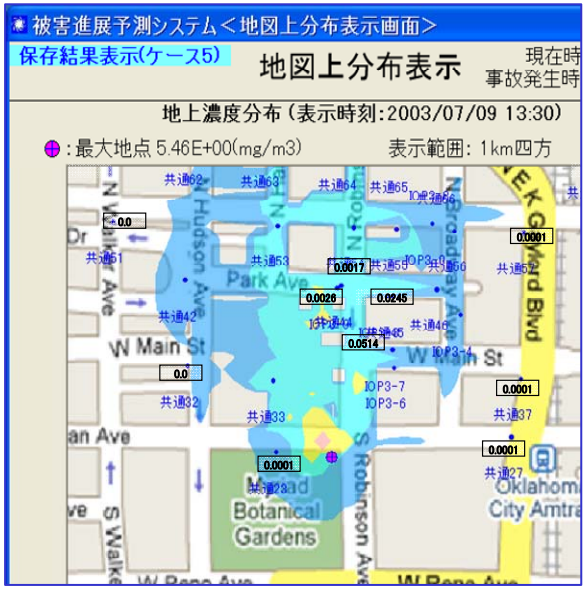
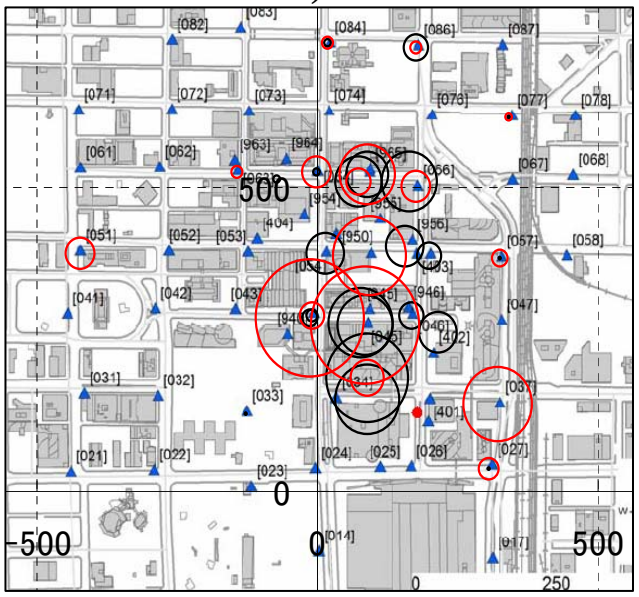


Comparison of gas concentration in Oklahoma

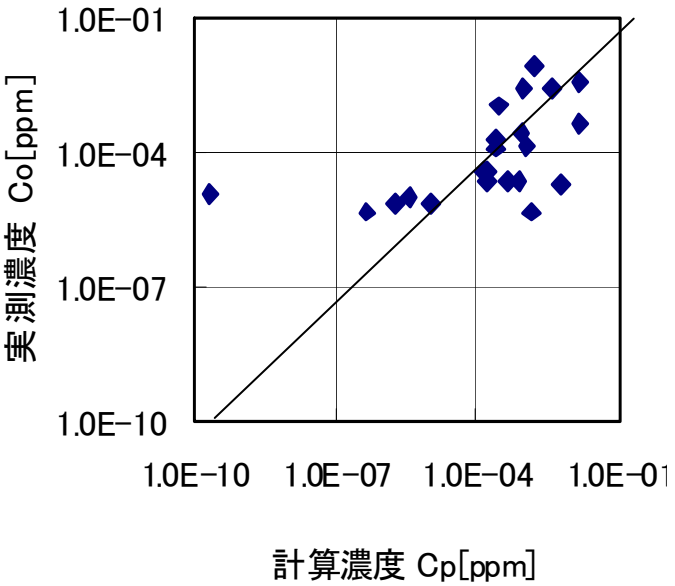
(a) Simulation of IOP4



(b) Comparison of gas concentration by diameter of circle (red: simulation, black: observation)



(c) Observed and predicted concentration



Improvement of database calculation scheme

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- Category of database: 16 wind directions, 1 stabilities (Neutral)

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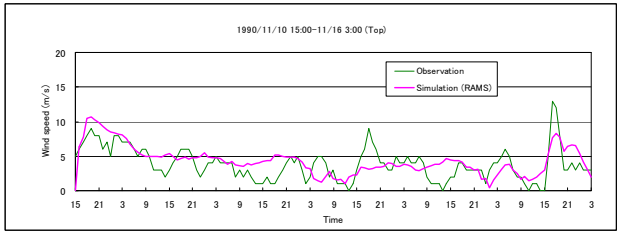
- Category of database: 16 wind directions, 3 stabilities (Neutral, stable and unstable)

Continuous simulation of meteorology for 1 year with coarse mesh > 1km →



Examples of results

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Classification of 8760 hourly simulated data into 48 cases →

	N	NNE	-	NNW
Neutral	10 hours	12 hours		9 hours
Stable	20 hours	8 hours		7 hours
Unstable	12 hours	6 hours		5 hours

↓

Selection of typical hourly simulated data for 48 cases →

	N	NNE	-	NNW
Neutral	10am 1^{t} Jan			
Stable	5pm 9 Feb			
Unstable				

↓

4D interpolation based on observed data with fine mesh <100m

Application to an emergency response system (1)

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Round table drill

Development of simulation system by MEXT project (2007 - 2009)

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Evaluation of applicability with emergency response drill by Tokyo metropolis (2009)

↓

Applied to other metropoli after 2010

Table 1 Emergency response items (Ref; US National Research Council report)

Response items		Time	Action plan
Pre-test	Drill	Routine	Imaginary scenario →round table drill→working drill
Actual accident	Emergency response	0 – 2 hours	Prediction of source terms
	Initial stage	2 – 12 hours	Making an evacuation plan based on real time simulation
	Second stage	12 – 24 hours	Decision making for recovery timing
	Recovery action	1 – few days	Detail reproduction of the public hazard

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Existing Techniques

- Atmospheric diffusion model
- Building ventilation model
- Evacuation assist technique
- Wind tunnel modeling

Integration

Total system of prediction and mitigation for CBR hazard

Sub theme 1,2 & 3 — Diffusion prediction system

Evacuation assist system

Input

Town-scale simplified evaluation

Macro-level pedestrian simulator

Evaluation

Queue network simulator

Planning assist system

Plan candidate

Route candidate

Evaluation

Micro-level pedestrian simulator

Man-level detailed evaluation

Input

Population data

CAD data

GIS data

Application

Realization of evacuation assist framework

Evacuation plan

Decision by rescue experts

・Candidates of evacuation plan and its evaluation