Development of Hazard Projection System for Intentional Attack in Urban Area

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Motivation

1. Background

- A variety of accidents sometimes occur everywhere.
  (Nuclear power plants, Chemical factory, Terrorism, etc.)
- Nowadays the simulation system predicting NBC agents dispersion is needed by the government or big cities.
- To develop the system, MHI is using Meso-scale meteorological model and dispersion model, RAMS/HYPACT.

2. Purposes of this study

- Development of hazardous gas dispersion simulator ,applying RAMS/HYPACT.
- Speed up the computational time.

Applications of MEASURES System

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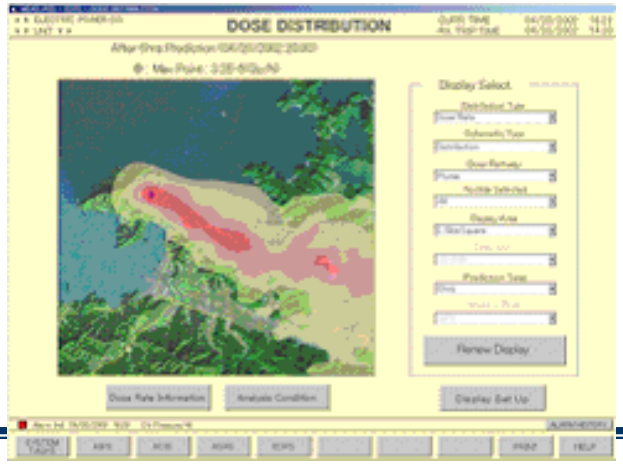
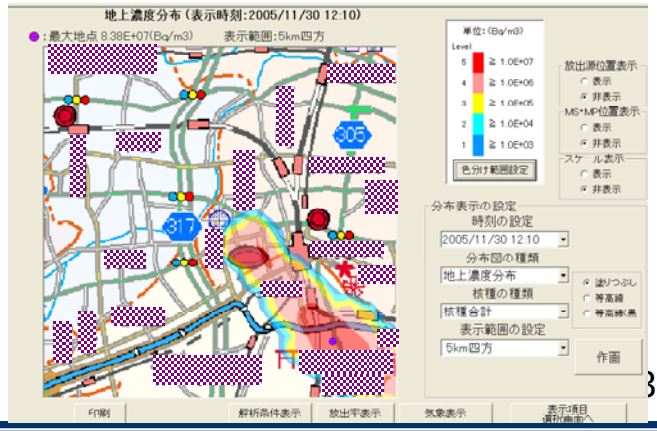
The hazardous gas dispersion simulator is technically based on MEASURES (Multiple Radiological Emergency Assistance System for Urgent Response) .

	MEASURES	Hazardous gas dispersion simulator
Objects	Accidents at nuclear P/S	NBC agents
Users	Government Electric Power Companies	Government Local government units
Area scale	Few 10 km	Few 100 m
Time scale	Few hours	Few 10 minutes
Mesh size	Few 100 m	Few meters
Simulation	Terrain	Terrain & Buildings
Computer	Parallel computer	Personal computer





Hazardous gas dispersion simulator

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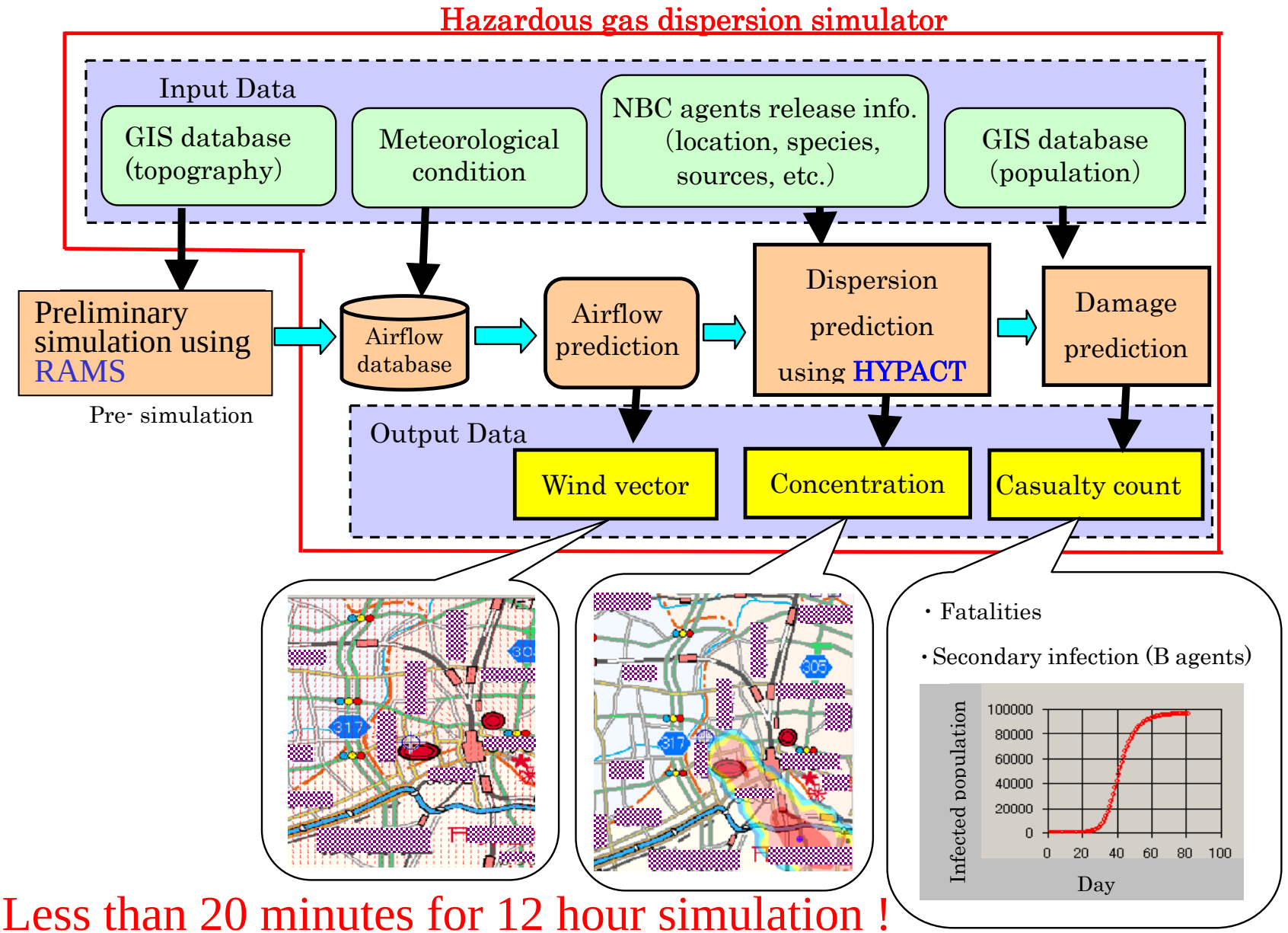

Less than 20 minutes for 12 hour simulation !

Airflow database

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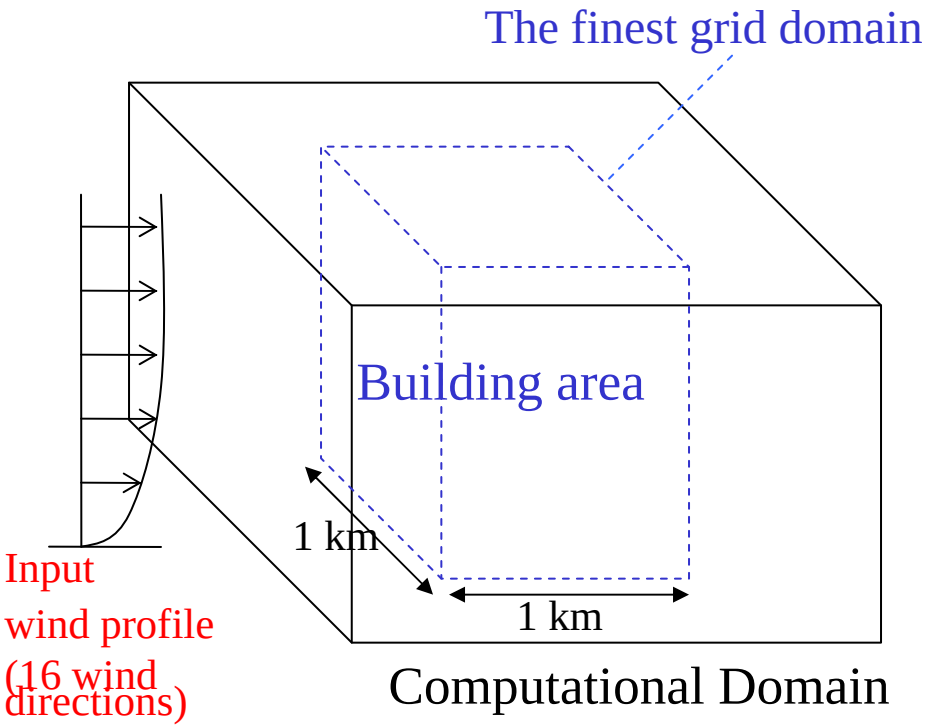
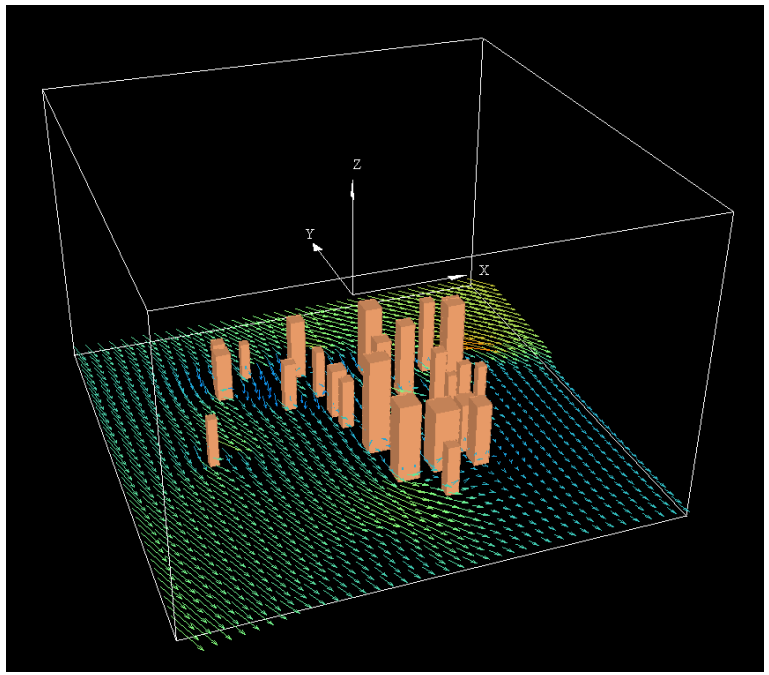
- Airflow data of 16 patterns corresponding 16 wind directions (N, NNE, NE, …., NNW) under neutral atmospheric conditions
- Pre-simulation using RAMS
- horizontal grid resolution : 10m
- buildings with more than 20 floors are set in the center area of the domain (1km squares)





RAMS simulation : Airflow

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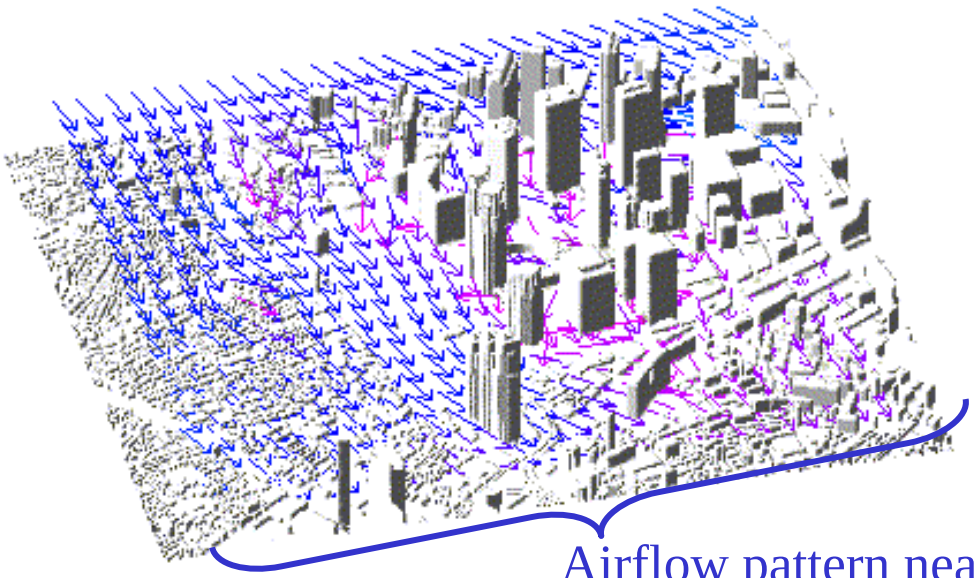

Airflow pattern near the ground

Examples of results from the dispersion simulator

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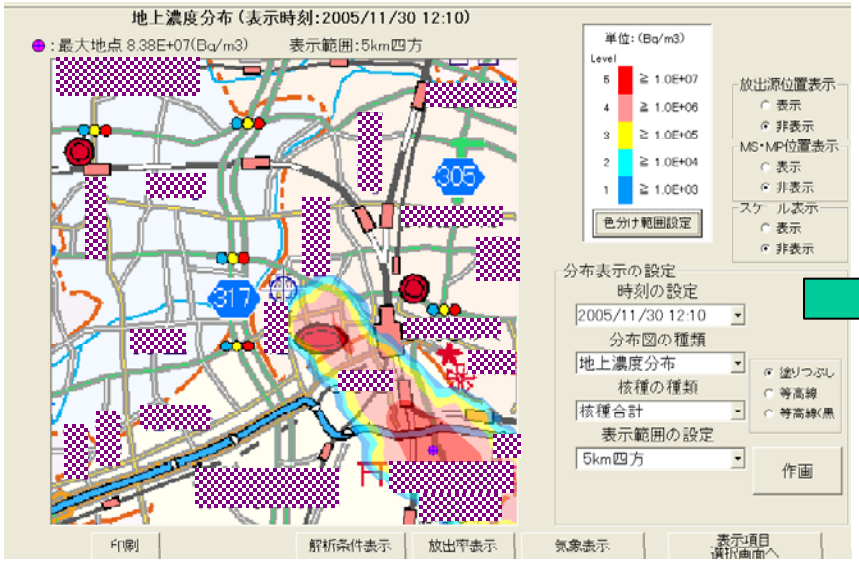
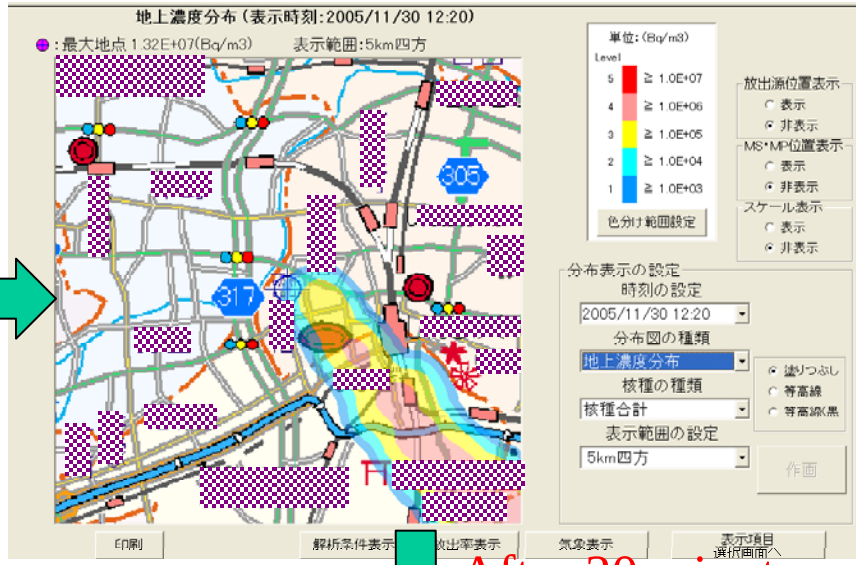




Gsa concentration: After 10 minutes

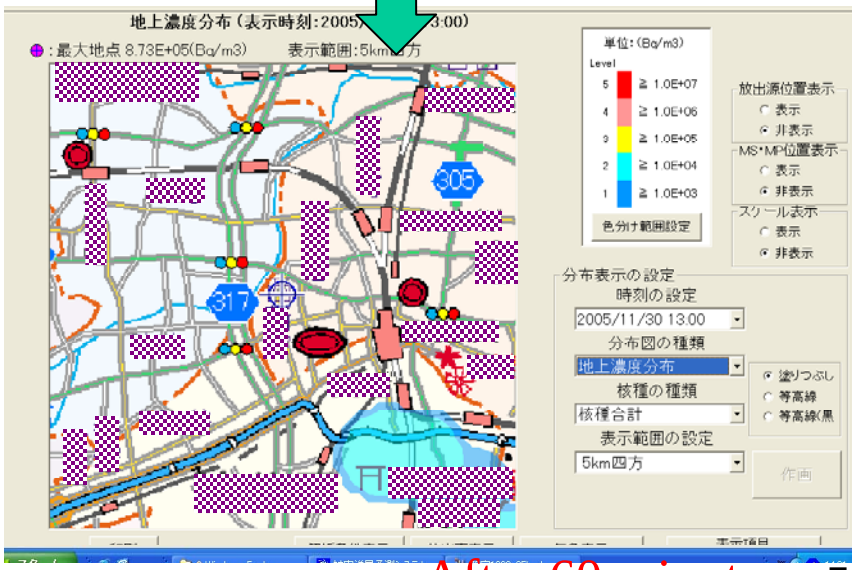
After 20 minutes

Release scenario

Wind : 5m/s (NW)

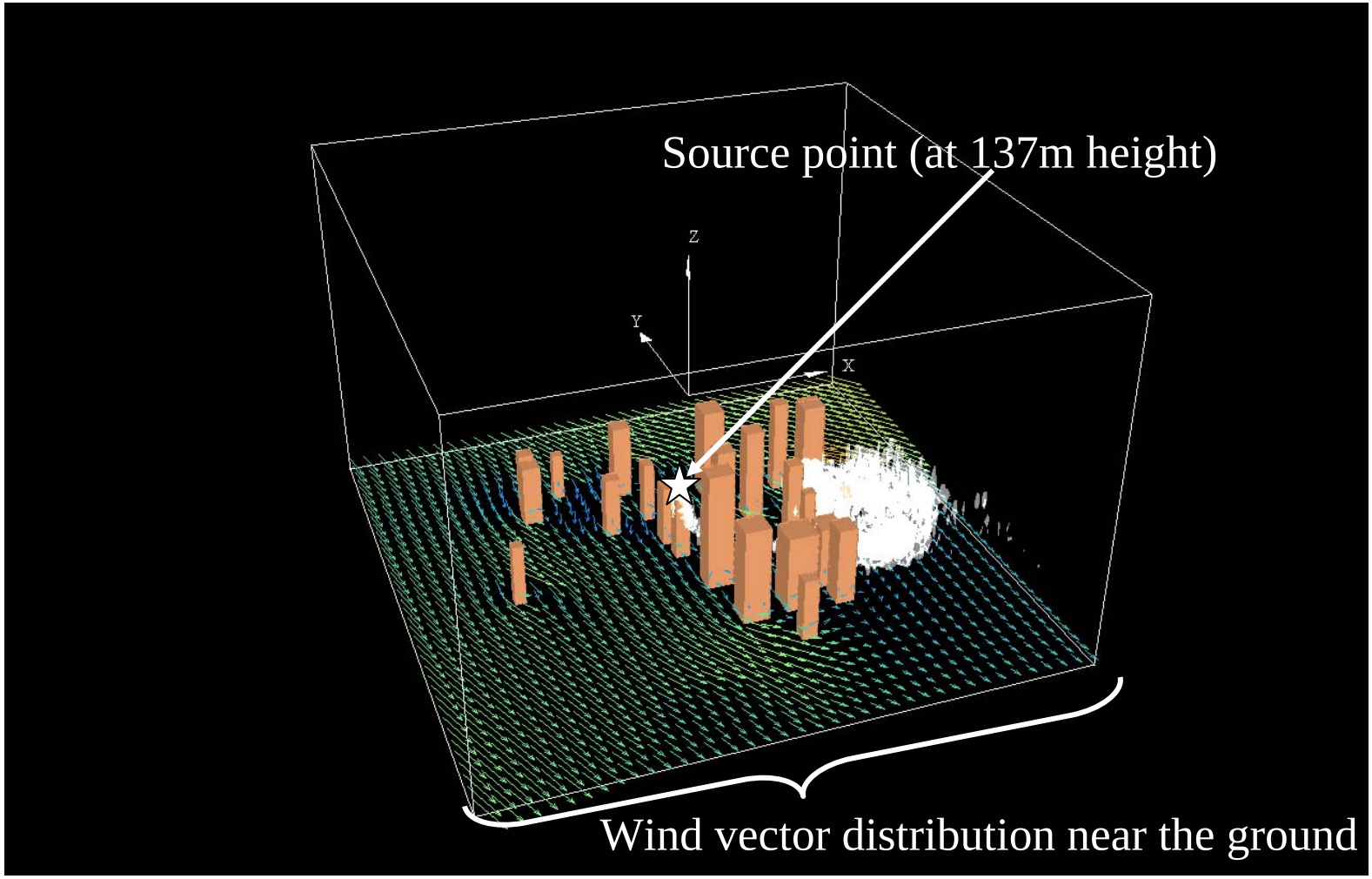
Species : Cs137 3kg

Source location : C hotel top
(137m AGL)



After 60 minutes

Examples of results from the dispersion simulator



the simulated concentration over building data

Automatization of creation of flow database

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Conventional system

Air flow data are pre-simulated manually and stored.

Taking a lot of time

Air flow database

Dispersion prediction

New system

A system for managing "airflow database creation"

Air flow database

Dispersion prediction

Parallel Computer

Interface

Air flow calculation

RAMS

Building shape data from digital map

This system enables us to speed up arranging the hazard projection system for the specific area.

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Summary

・We developed dispersion simulator for NBC agents.
This simulator can predict not only concentration of NBC agents but also number of casualties.

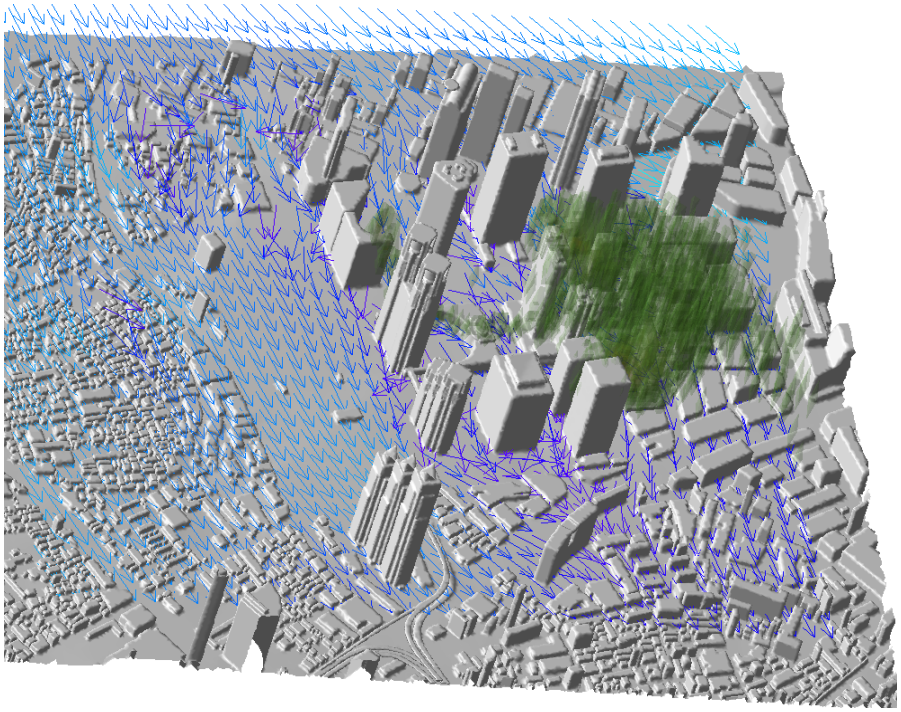
・The simulator attains less than 20 minutes for 12 hour prediction, by making use of airflow database by RAMS.

・A system for managing “airflow database creation” was newly developed. This system enables us to speed up arranging the hazard projection system for the specific area.

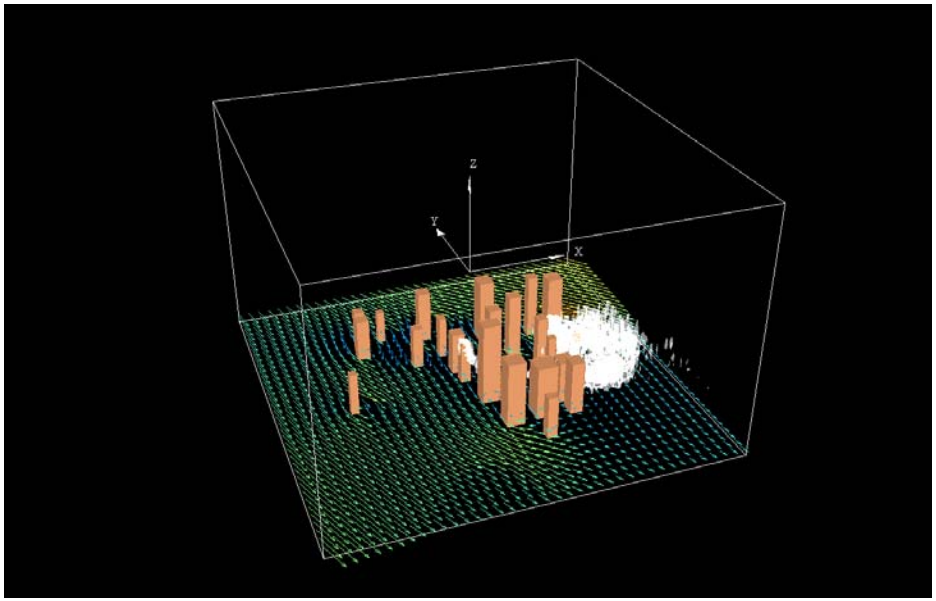
・The investigation on accuracy of this dispersion prediction scheme is undergoing by using Joint urban 2003 data.

Acknowledgements
This study is funded by MEXT (Ministry of Education, Culture, Sports, Science and Technology) of Japan.

RAMS & HYPACT simulation



Building CAD data



Actual RAMS data

ADAP coordinate in RAMS ver.5.0

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・Cartesian grid

・The “apertures” of grid cell faces are open or closed depending on the presence of topography or buildings

・Finite volume method are applied.

Ex.) horizontal advective term in the x-direction of an arbitrary scalar field.

$$-\frac{1}{\rho}\left(\frac{\partial \rho u \phi}{\partial x}+\phi\frac{\partial \rho u}{\partial x}\right)=-\frac{1}{\rho_j \Delta V_j}\left[\left(\left(\rho FA\right)_{j+1/2}-\left(\rho FA\right)_{j-1/2}\right)-\phi_j\left(\left(\rho uA\right)_{j+1/2}-\left(\rho uA\right)_{j-1/2}\right)\right]$$

A: grid cell apertures (m^2)

Ref.) C.J.Tremback, R.L. Walko, Implementing Very-High Resolution Capabilities into a Mesoscale Atmospheric Model: New Capabilities for the Regional Atmospheric Modeling System (RAMS)

Improved building scheme in ver.5.0

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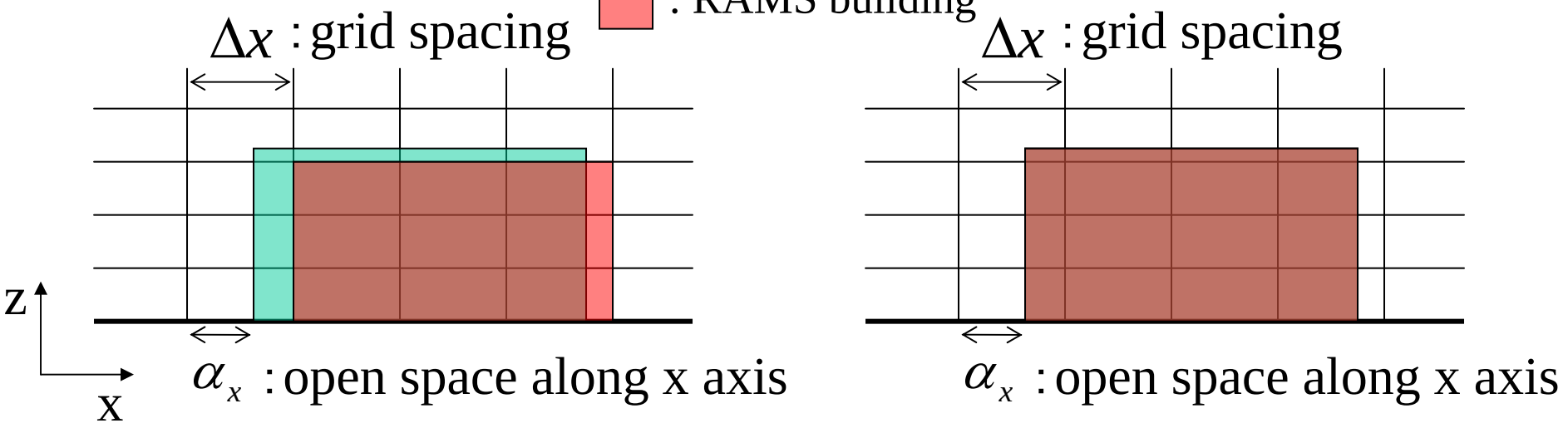
Original scheme

Improved scheme

: Actual building

: RAMS building



IF $\frac{\alpha_x}{\Delta x} \le 0.5$ *or* $\frac{\alpha_y}{\Delta y} \le 0.5$ *or* $\frac{\alpha_z}{\Delta z} \le 0.5$

THEN

Grid cell apertures (m^2) : Au=0, Av=0, Aw=0

Grid cell apertures (m^2) :

$Au = Au \times \frac{\alpha_x}{\Delta x}$, $Av = Av \times \frac{\alpha_y}{\Delta y}$

$Aw = Aw \times \frac{\alpha_z}{\Delta z}$

Test simulation with a single building

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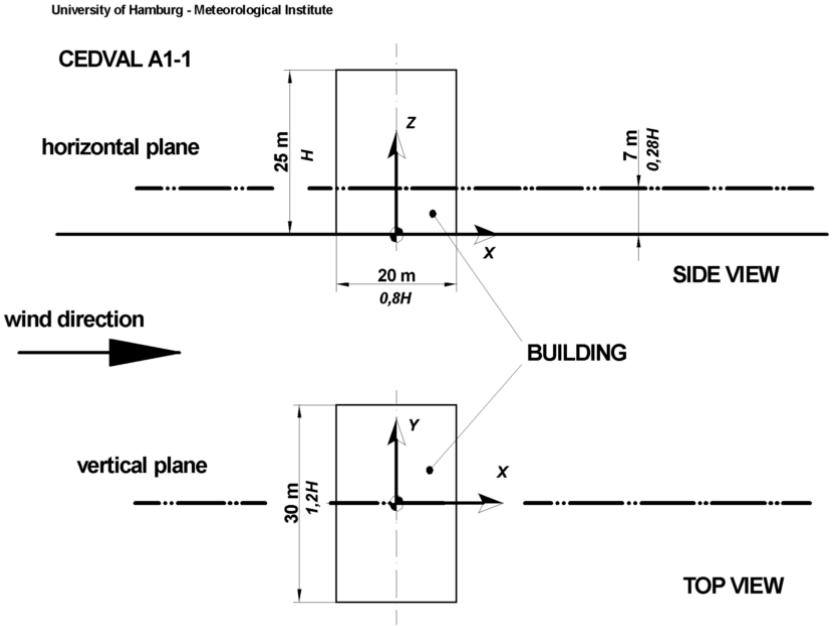
- Use of RAMS ver.5.0 with the improved building scheme
- Grid spacing of x, y, z : 2.0m
- Number of grid cells : 160 * 120 * 50 = 1 million
- Turbulent model: Isotropic E-l closure model implemented in RAMS ver.5.0 (Castelli, 2004)
- Comparison with Wind tunnel experiments carried out in Hamburg Univ. (http://www.mi.uni-hamburg.de/cedval/)



Comparison of Flow fields

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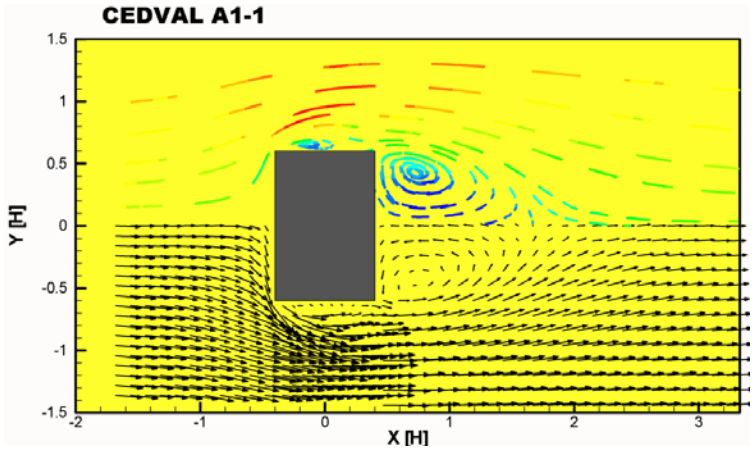
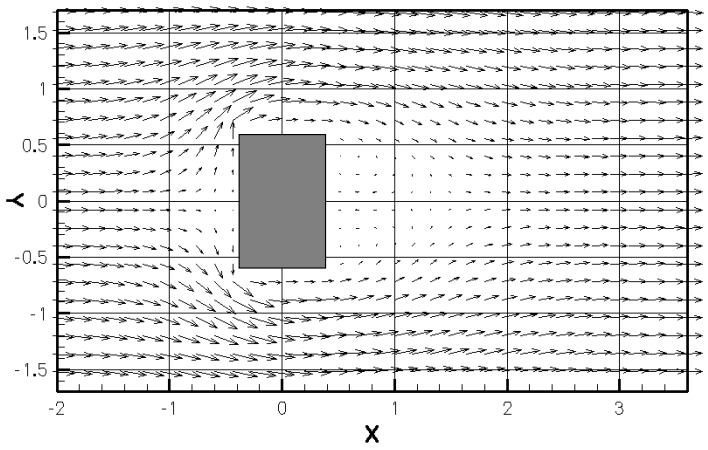
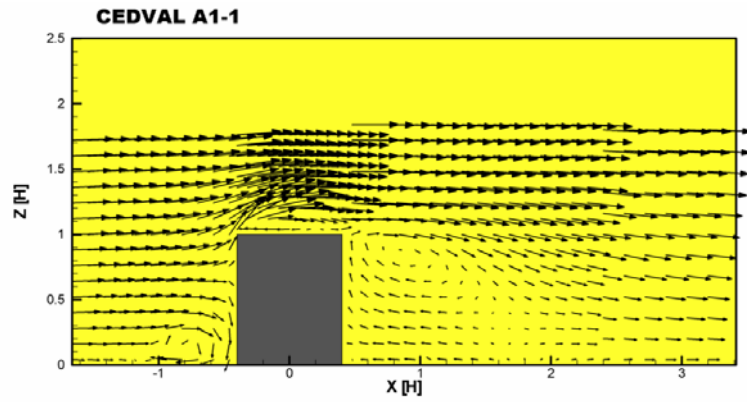
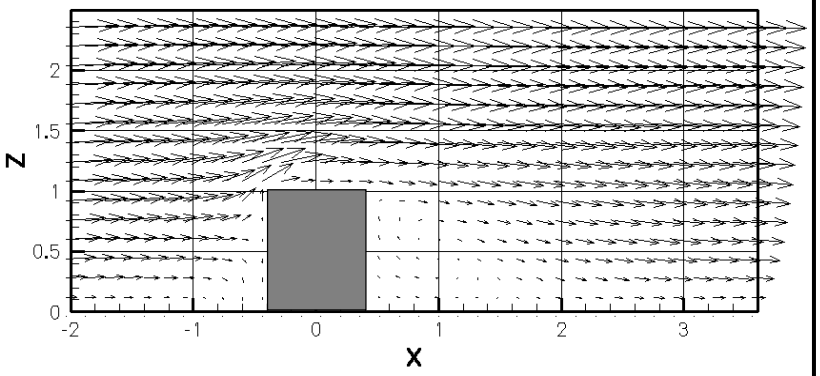
Horizontal section





Vertical section





Wind Tunnel experiment

Improved RAMS

Comparison of Wind speed profile

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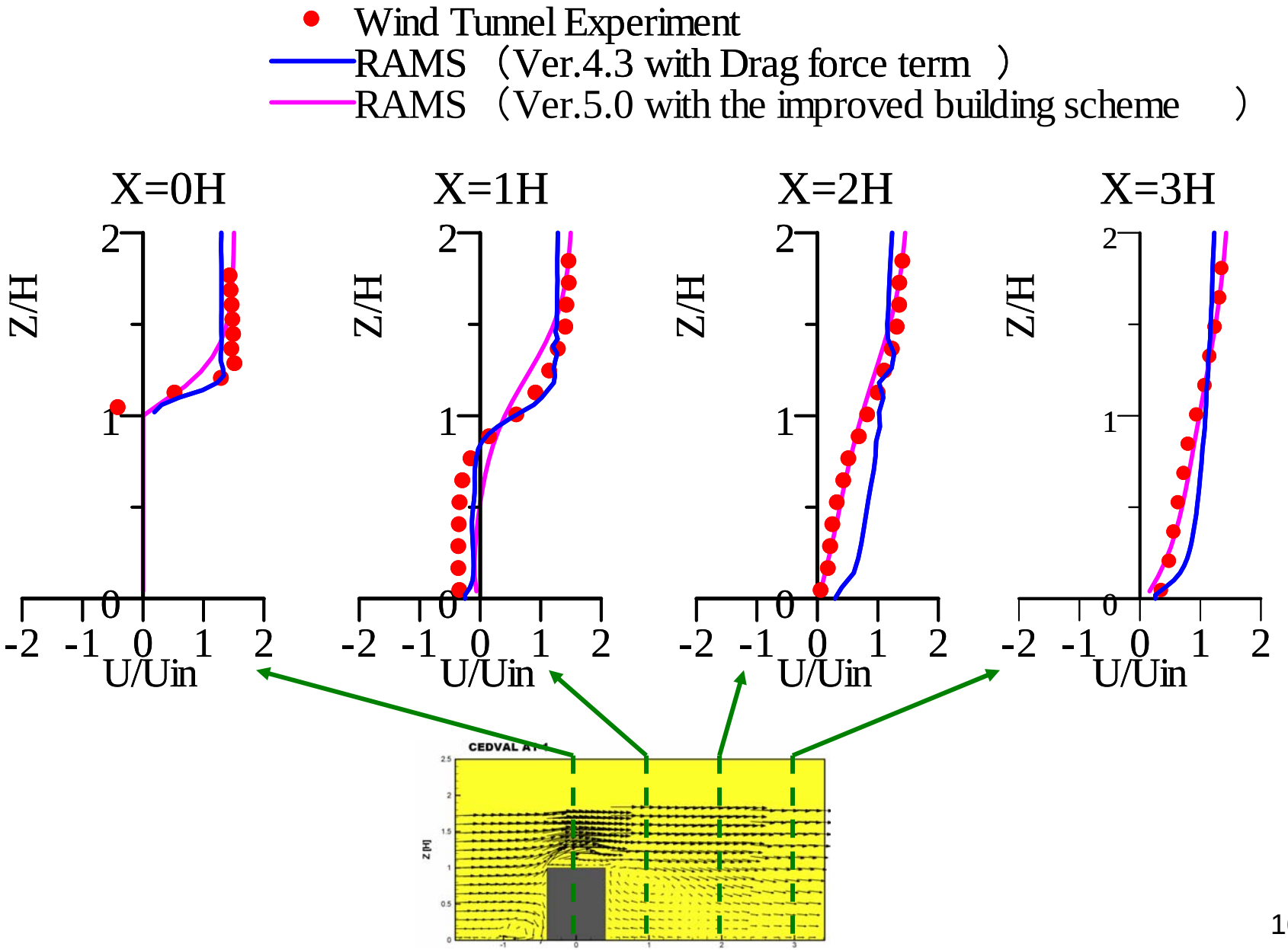

Simulation with Multi buildings

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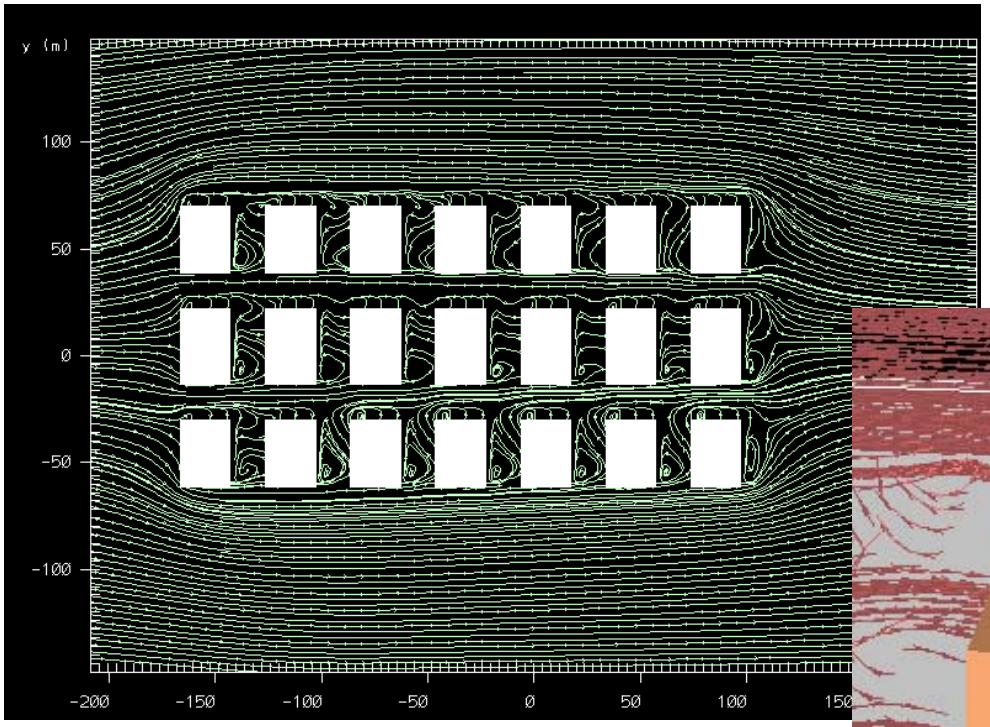
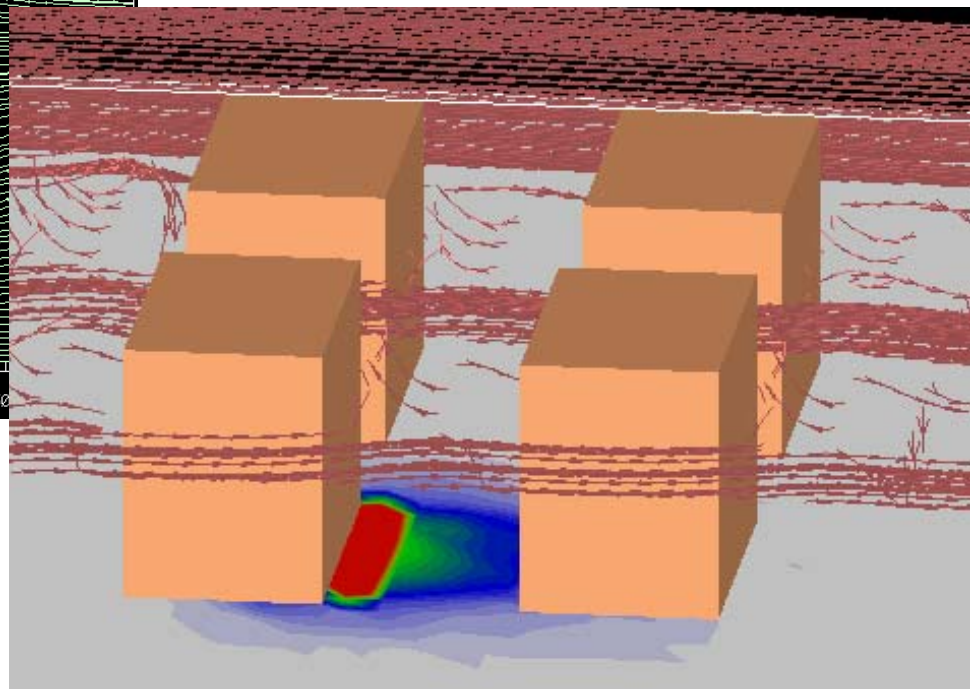
Stream lines in the horizontal section





Stream lines and Concentration field

Local 4D Assimilation Technique

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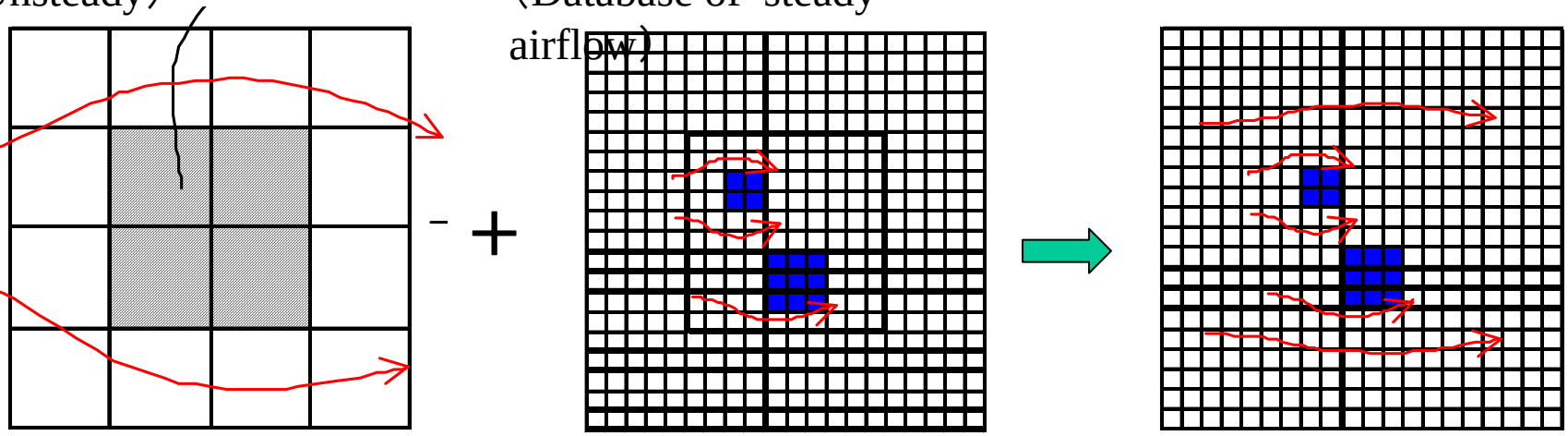
a) Few 100 m mesh

(Unsteady)

b)Few 10 m mesh

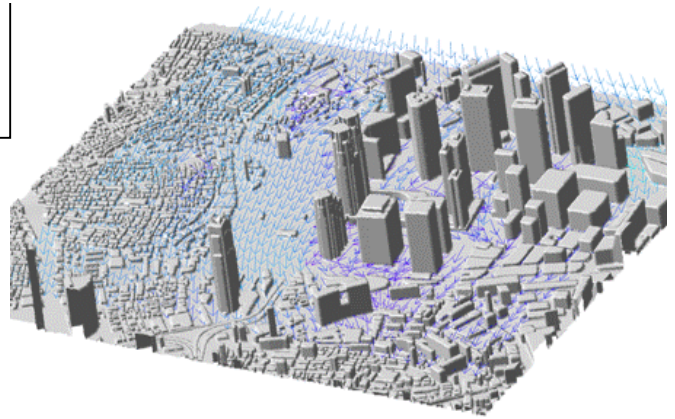
(Database of steady airflow)

c) Local 4D Assimilation
(Nudging at boundary)



Computational time of 12 hour simulation（24CPU×2GHz)

Model	100 m <	100 m >	Total
Present model	Few 10 min.	Few sec	Few 10 min.
Conventional	100 min.	2000 min.	Few 10 hrs



Air flow around tall buildings

Parallel computing technique (1)

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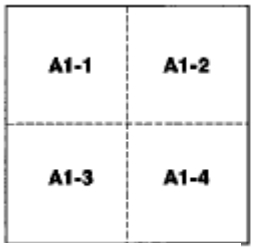
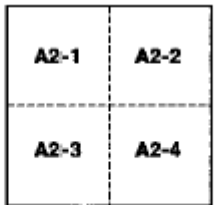
a) Conventional (Domain Decomposition Method : DDM)

Each domain by Each CPU

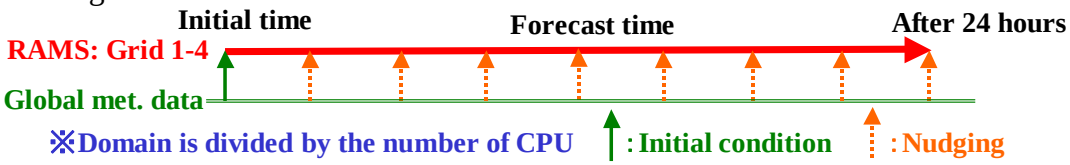


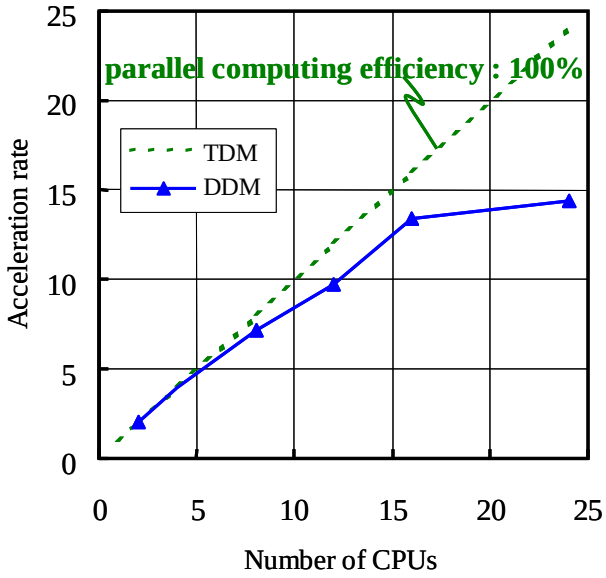
Large area : A1



Middle area : A2

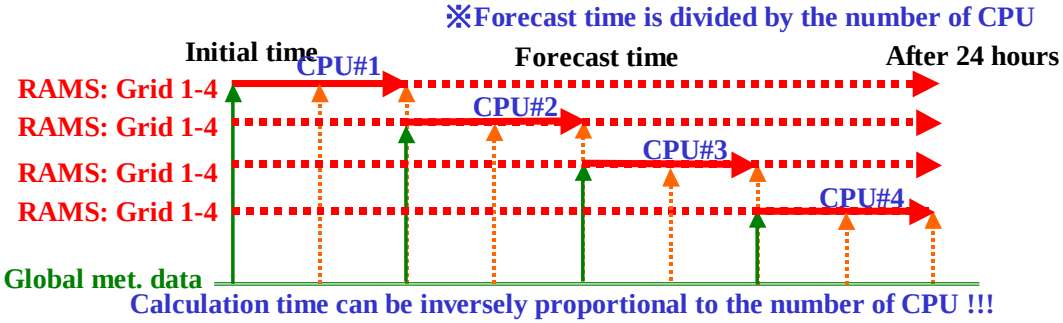
Small area : A3

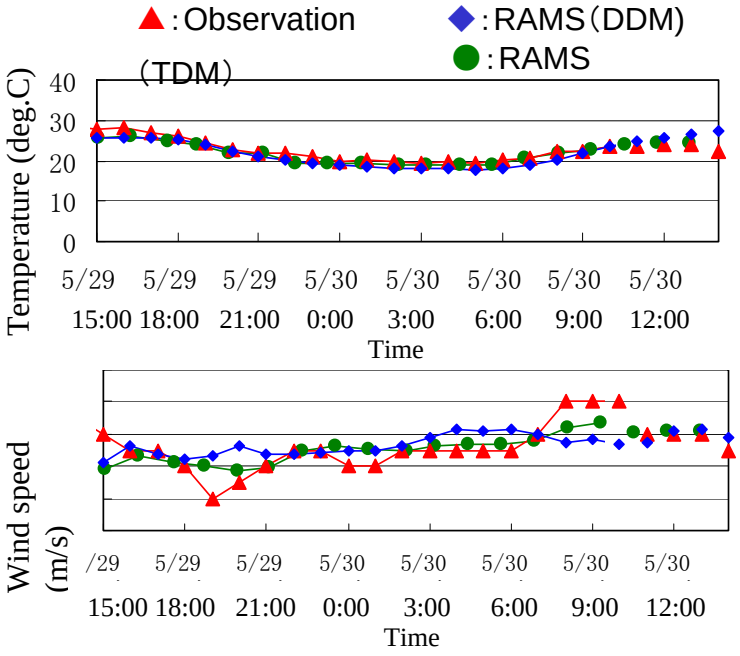




b) New-1 (Time Decomposition Method : TDM)

Each time by Each CPU



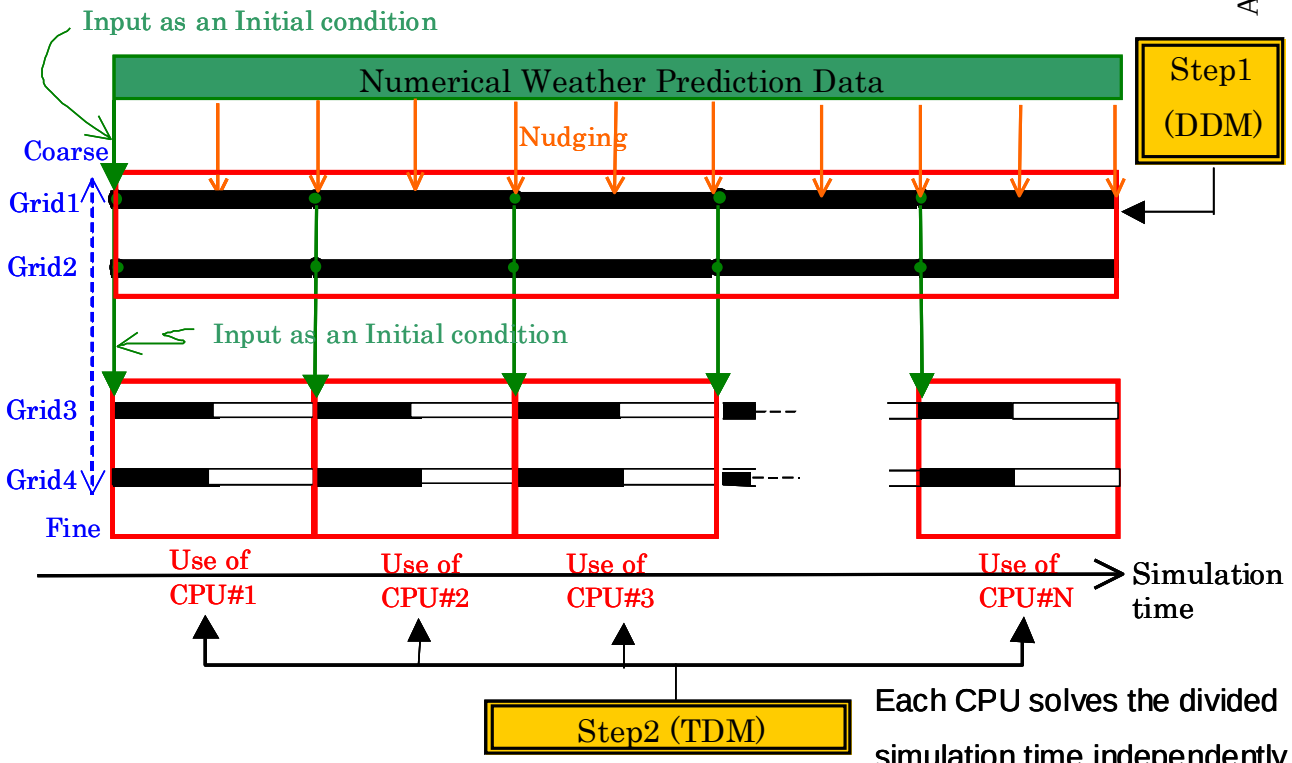


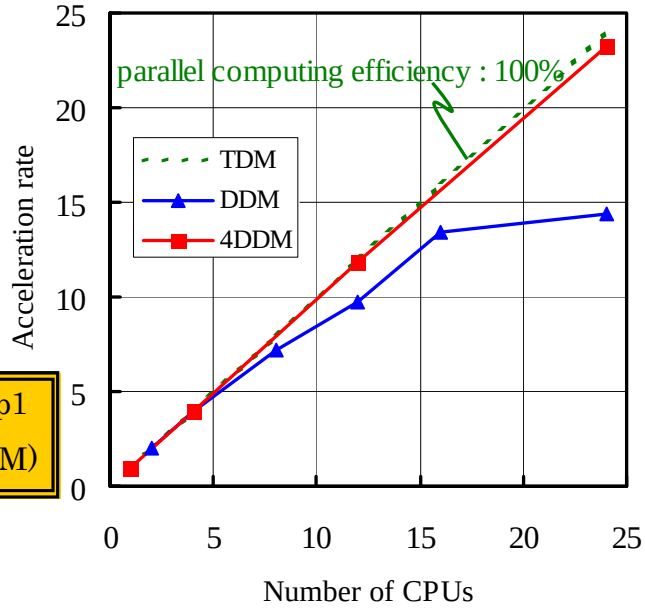
Parallel computing technique (1)

c) New-2 (4D Decomposition Method : 4DDM)

1st step: Domain Decomposition Method for coarse mesh

2nd step: Time Decomposition Method for fine mesh





Each CPU solves the divided simulation time independently.

US patent number : US6,801,856