

# Numerical Simulation of Snow Accretion by Airflow Simulator and Particle Simulator

Kohei Murotani, Koji Nakade, Yasushi Kamata, (Railway Technical Research Institute)

## Objective and Motivation

Snow is accreted to the bogies of running trains in the snowy area (see the figure on the right). When the lump of snow falls off the bogies, it might damage railway ground facilities along to tracks, vehicles, and people's houses along the railway line. To prevent such damage, snow accretion on the bogies is removed by human power at stations. Though the various facilities and houses in the snowy area often suffered from the snow accretion damage, the snow accretion mechanism has not yet been made clear.

To establish countermeasures against the snow accretion damage, we have developed a simulator of realizing the snow accretion process in the following steps. Firstly, air flow analysis is performed by "Airflow simulator" developed by RTRI (Railway Technical Research Institute). Secondly, trajectory of flying snow is calculated by Basset-Boussinesq-Oseen equation using distribution of velocity of air flow. Thirdly, snow accretion analysis is performed by "Particle simulator" developed by RTRI. The bogie shape changed by snow accretion is take into consideration to the boundary conditions of the air flow analysis.

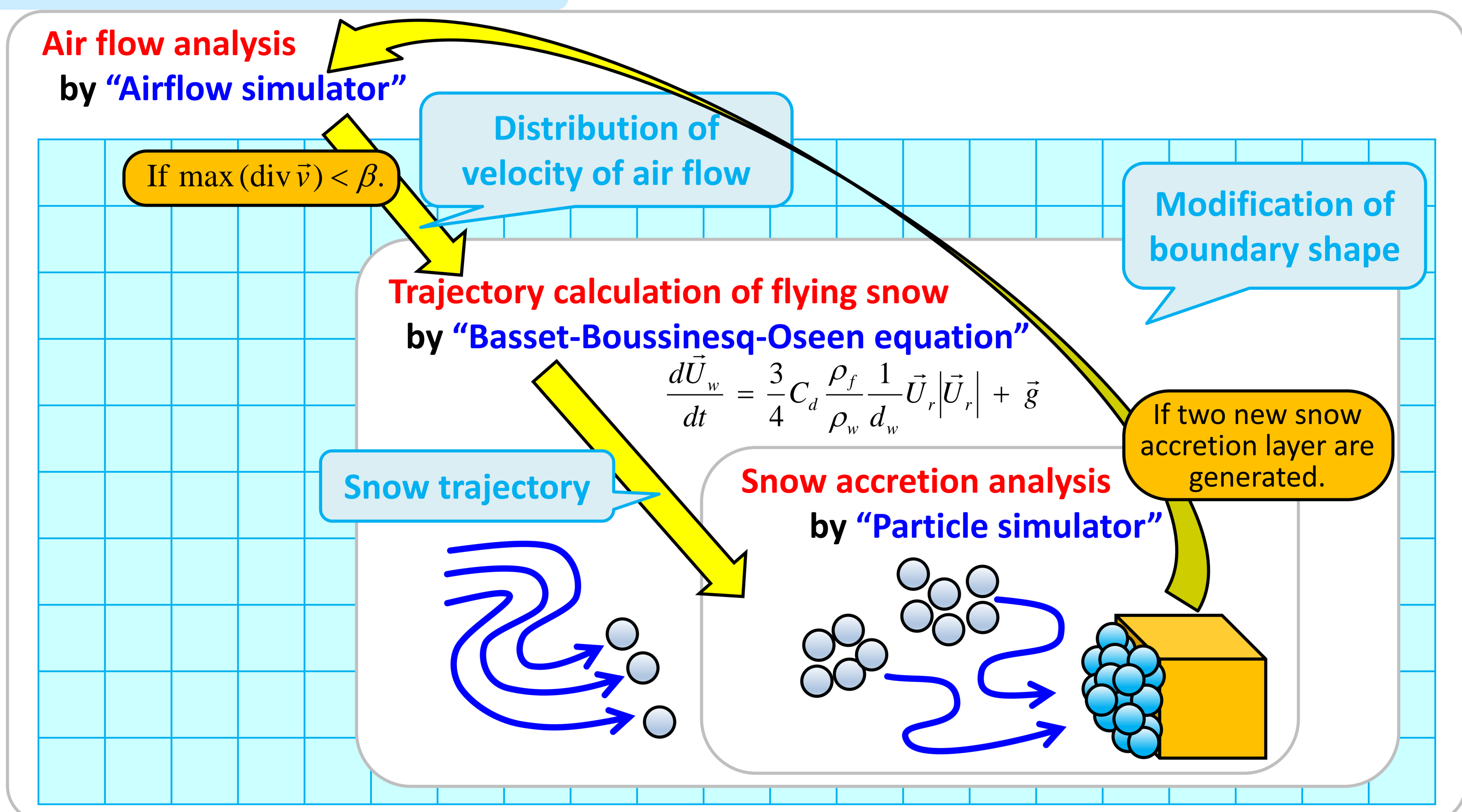
In this year, snow accretion analysis for simple cubic shapes has been performed in order to aim at development of simulation system of analyzing the snow accretion process and its validation.



"Snow Accretion on Train Bogies"

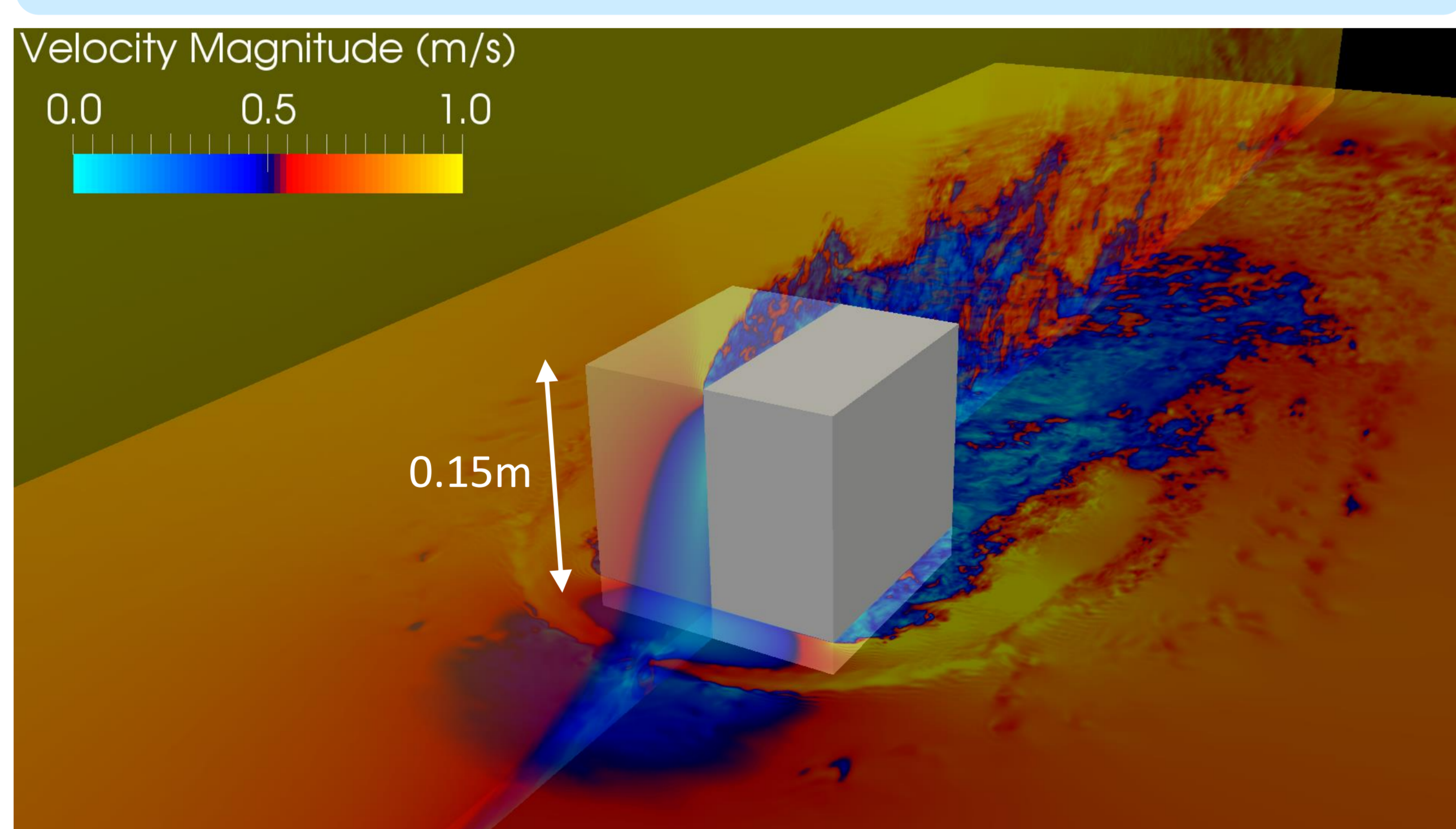
Y. Kamata, D. Takahashi, Y. Kurihara, A. Yokokura, S. Iikura: Method of Predicting the Snow Accretion Amount on Train Bogies in Consideration of Snow Properties on the Track, RTRI report, Vol.29, No.1, pp.11-16, 2015.

## Snow accretion analysis



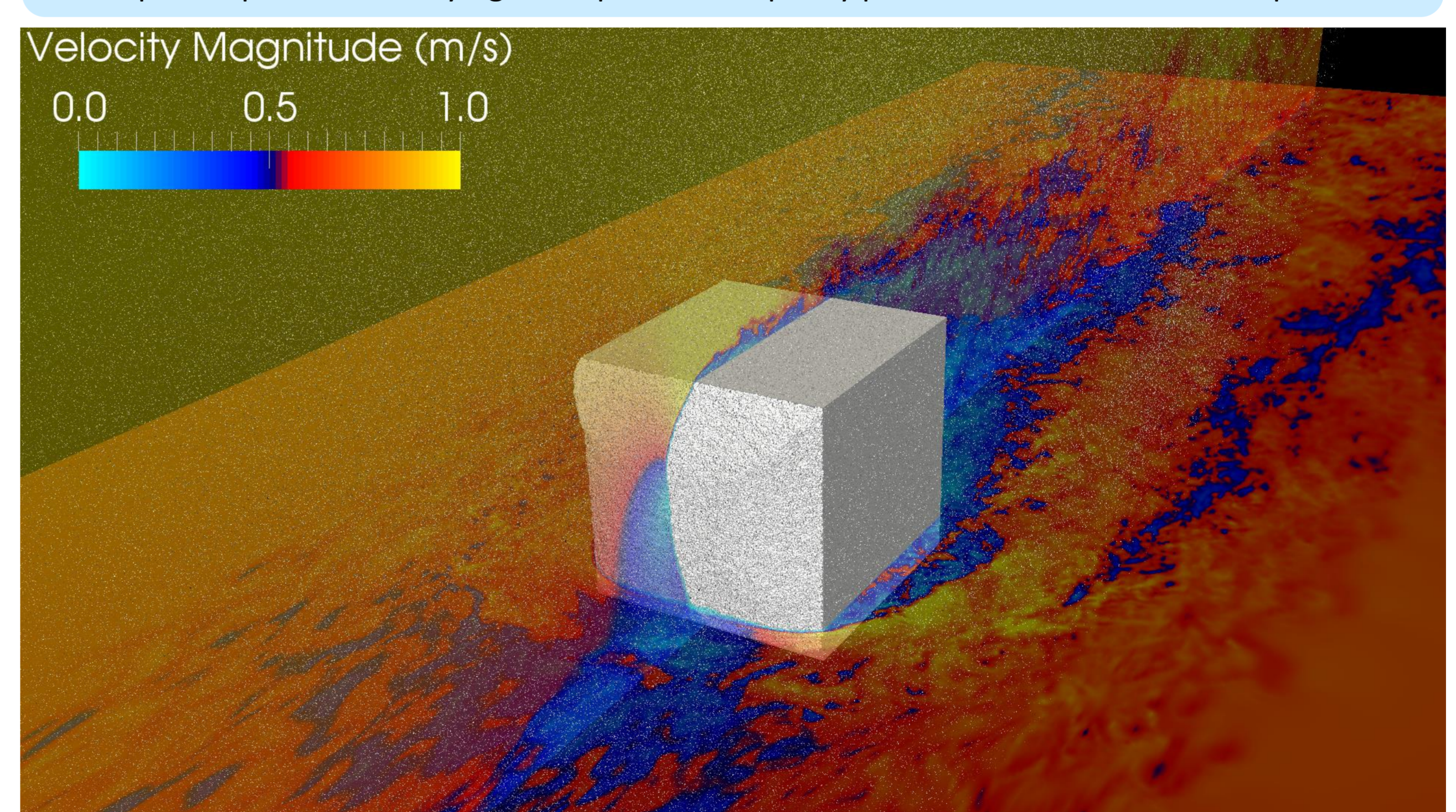
### Result of air flow analysis

Sectional view of velocity magnitude at y=0m and z=0.02m.



### Result of snow accretion analysis and air flow analysis

Transparent particles are flying snow particles. Opacity particles are snow accretion particles.



### Condition of air flow analysis

- Analysis conditions
- ✓ Analysis area: 2.5m × 1m × 1m
  - ✓ 140 million grids (700x500x400)
  - ✓ Minimum grid spacing: 1mm
  - ✓ Time: 10s, dt: 10<sup>-4</sup>s
  - ✓ About 200,000 steps (including balancing loop)
- Computational performances
- ✓ 1,200 nodes of K computer
  - ✓ Total wall-clock time: 6,000s

### Condition of snow accretion analysis

- Analysis conditions
- ✓ Analysis area: 1m × 0.4m × 0.4m
  - ✓ 5 million particles
  - ✓ Particle diameter: 1mm
  - ✓ Time: 10s, dt: 10<sup>-4</sup>s
  - ✓ 100,000 steps
- Computational performances
- ✓ 1,200 nodes of K computer
  - ✓ Total wall-clock time: 800s

# Numerical Simulation of Snow Accretion by Airflow Simulator and Particle Simulator

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## Supercomputer used in this research

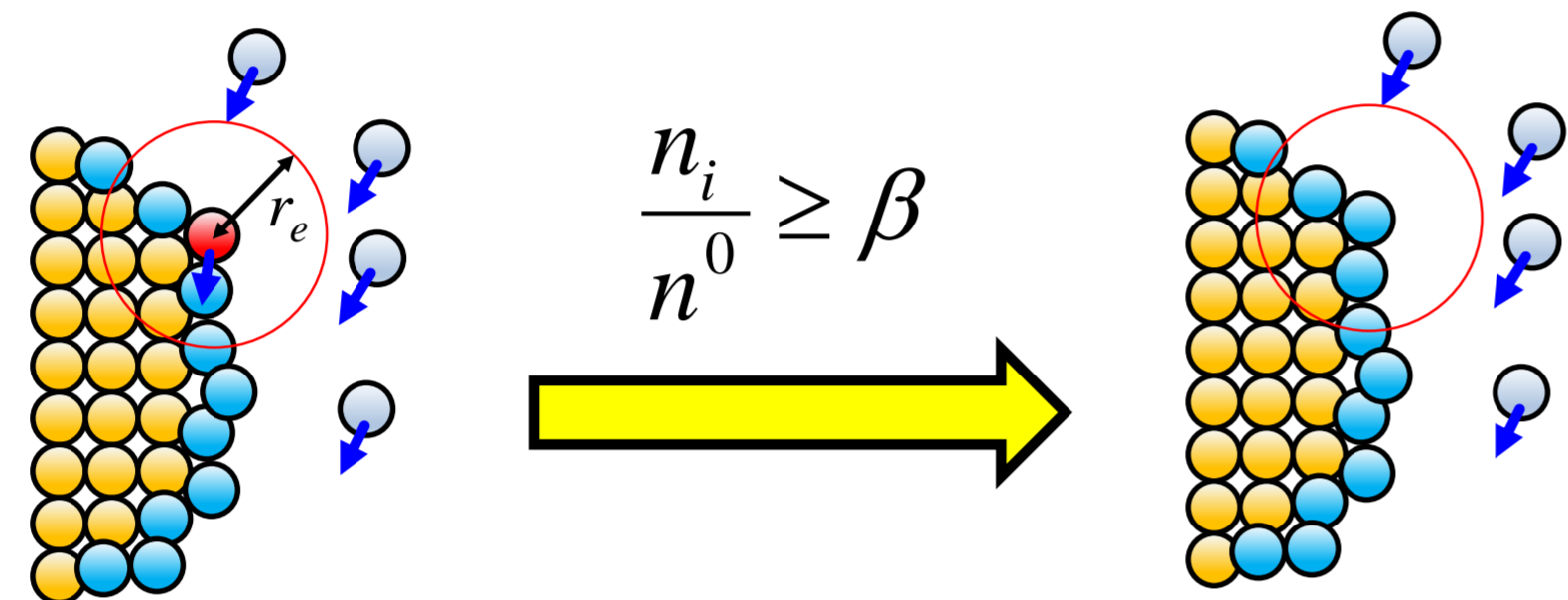
System	Site	Processor (peak FLOPS)	Nodes	Top500 (June '17)	HPCG (June '17)
K computer	RIKEN	2.0 GHz SPARC64 VIIIfx, 8-Core (128 GFLOPS)	88,128	8	1

## ACKNOWLEDGMENTS

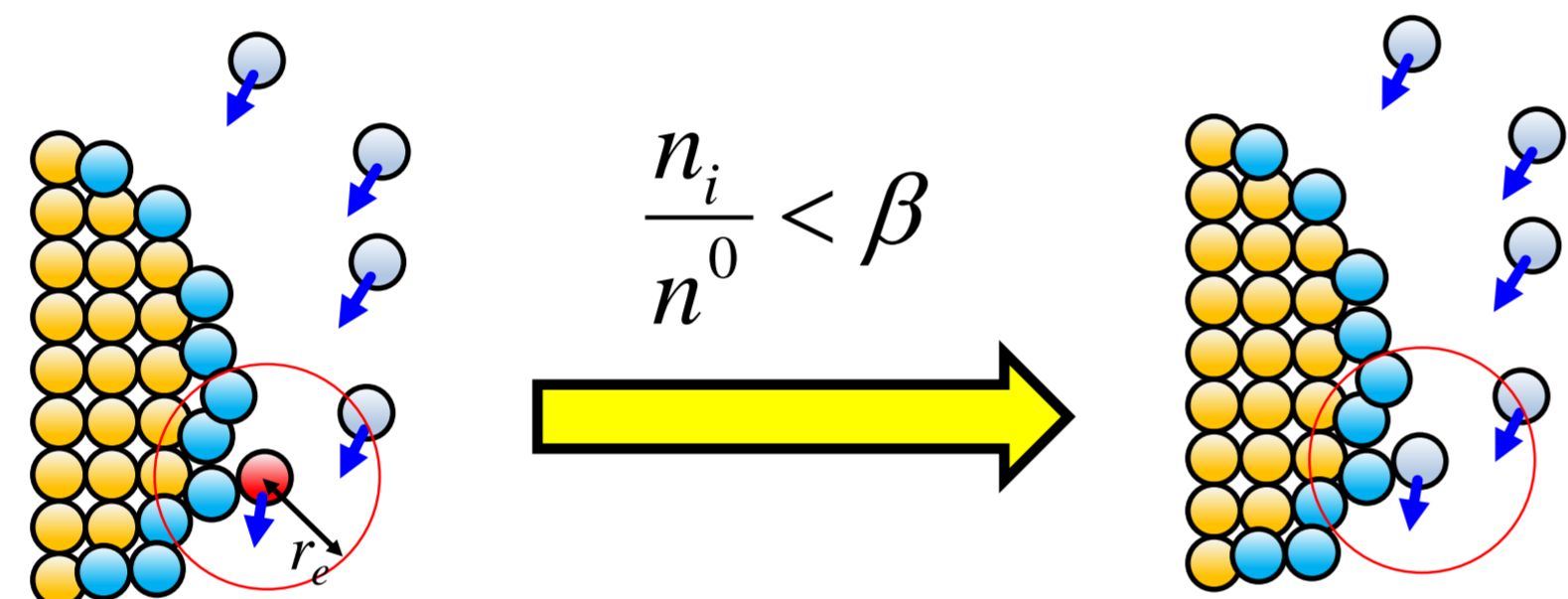
This research used computational resources of the K computer provided by the RIKEN Advanced Institute for Computational Science through the HPCI System Research project (Project ID: hp170067). This work was supported by JSPS KAKENHI Grant Number 17K05152.

## Snow accretion algorithm

If  $\frac{n_i}{n^0} \geq \beta$ , then the **target particle** becomes "snow accretion particle".



If  $\frac{n_i}{n^0} < \beta$ , then the **target particle** is still "flying snow particle".



- Wall particle
- Snow accretion particle
- Flying snow particle
- Target particle

$\beta$  is threshold parameter (0.65 in this research).

Space filling rate  $\frac{n_i}{n^0}$

Particle number density  $n_i = \sum_{j \neq i} w(\|\vec{r}_{ij}\|)$

Weight function  $w(\|\vec{r}_{ij}\|) = \begin{cases} \left(\frac{\|\vec{r}_{ij}\|}{r_e} - 1\right)^2 & (0 \leq \|\vec{r}_{ij}\| \leq r_e) \\ 0 & (r_e < \|\vec{r}_{ij}\|) \end{cases}$

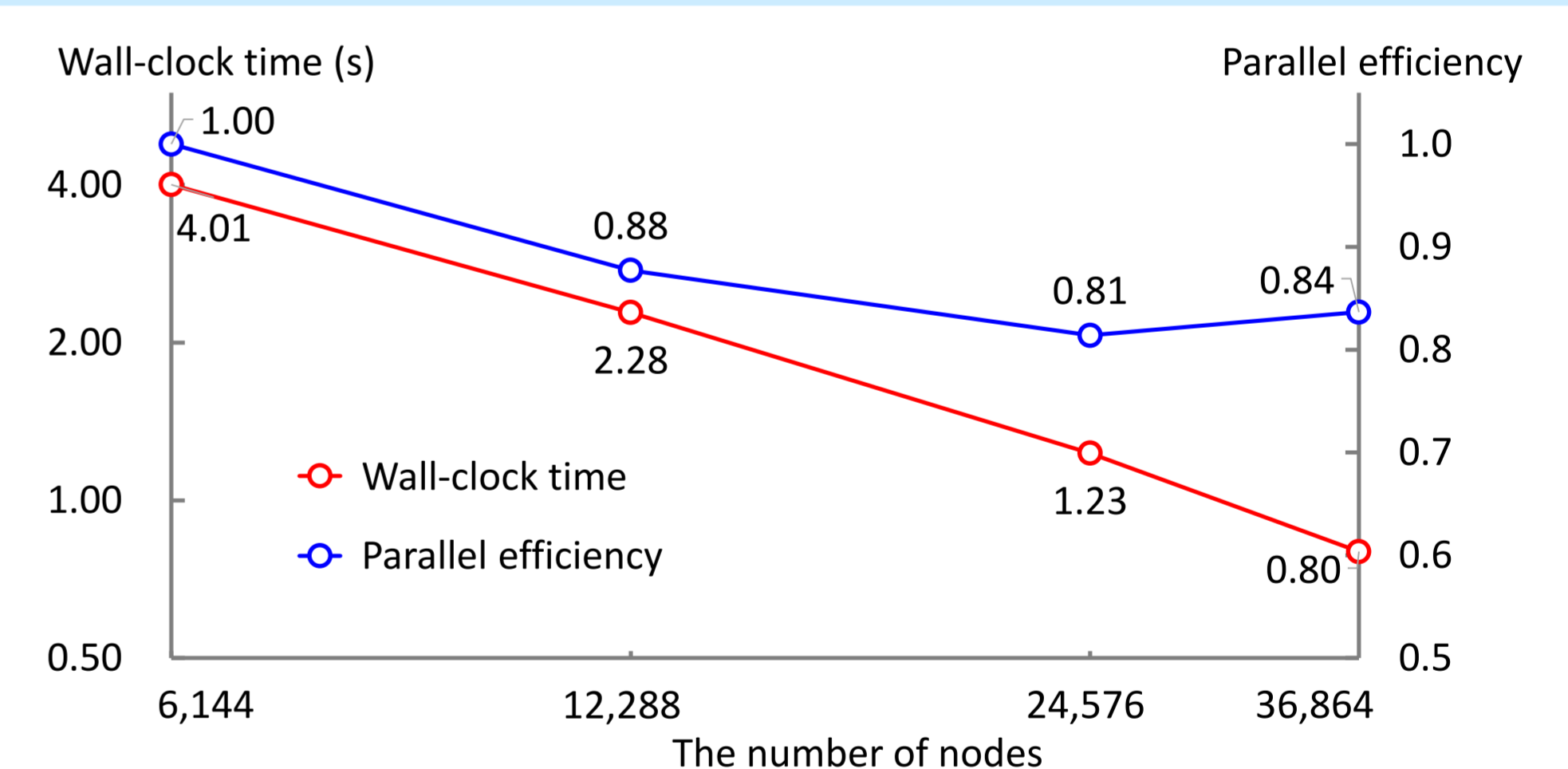
## Airflow simulator

### Overview

- Navier-Stokes equation for Incompressible fluid flow
- Finite difference method for nonuniform grid
- Fractional step method
- 2nd-order central difference
- 3rd-order Adams-Bashforth methods
- Poisson equation solver by Jacobi method
- LES model by coherent structure Smagorisky model

- Parallel computing
  - Orthogonal domain decomposition
  - Communication by Halo exchange
- Target problem size
  - 10 million - 100 billion grids
- Development and operating environment
  - OS : UNIX, Linux
  - Compiler : Fortran 90
  - Communication library : MPI

### Strong scaling of 100 billion grids by K computer



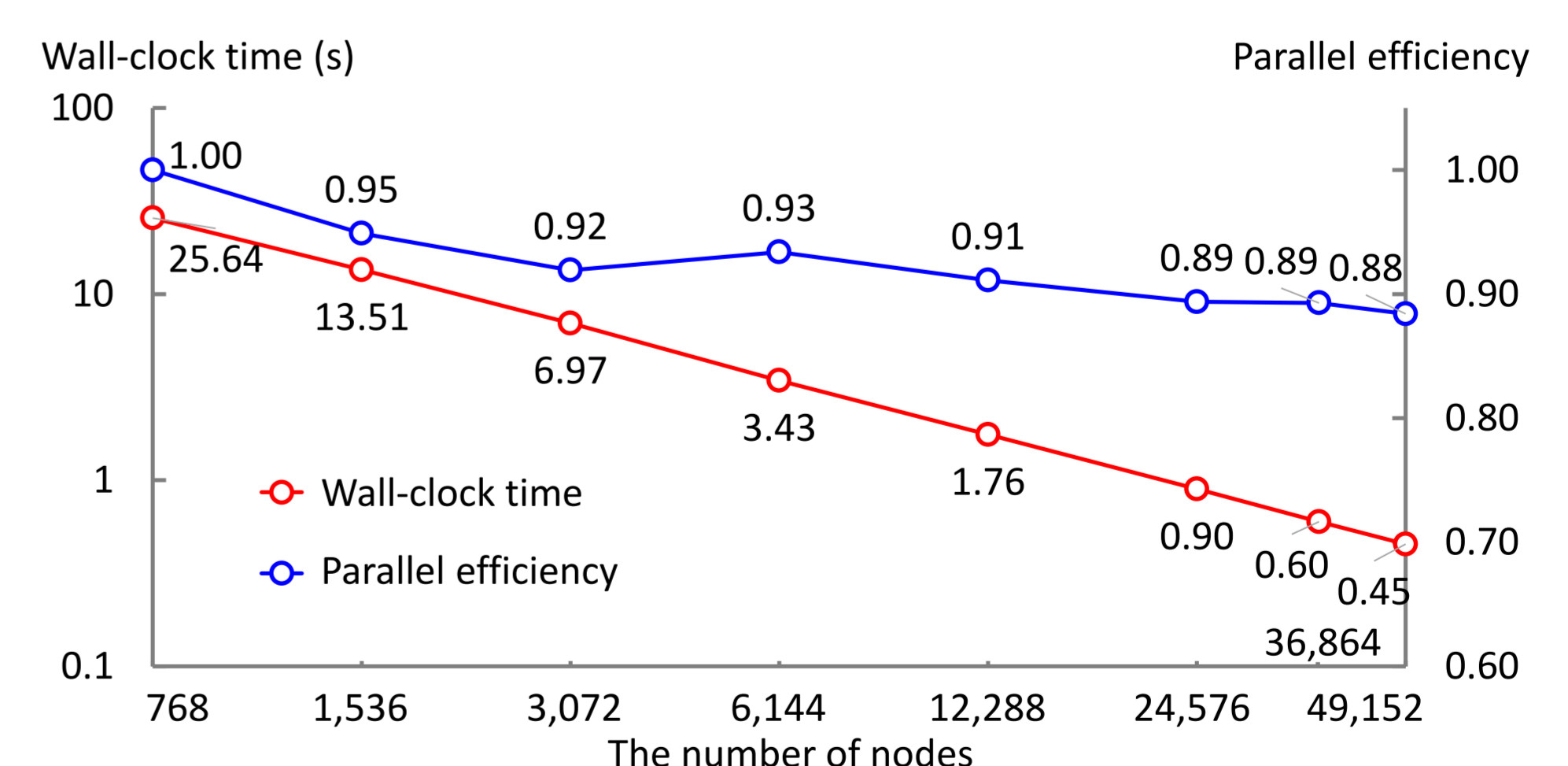
## Particle Simulator

### Overview

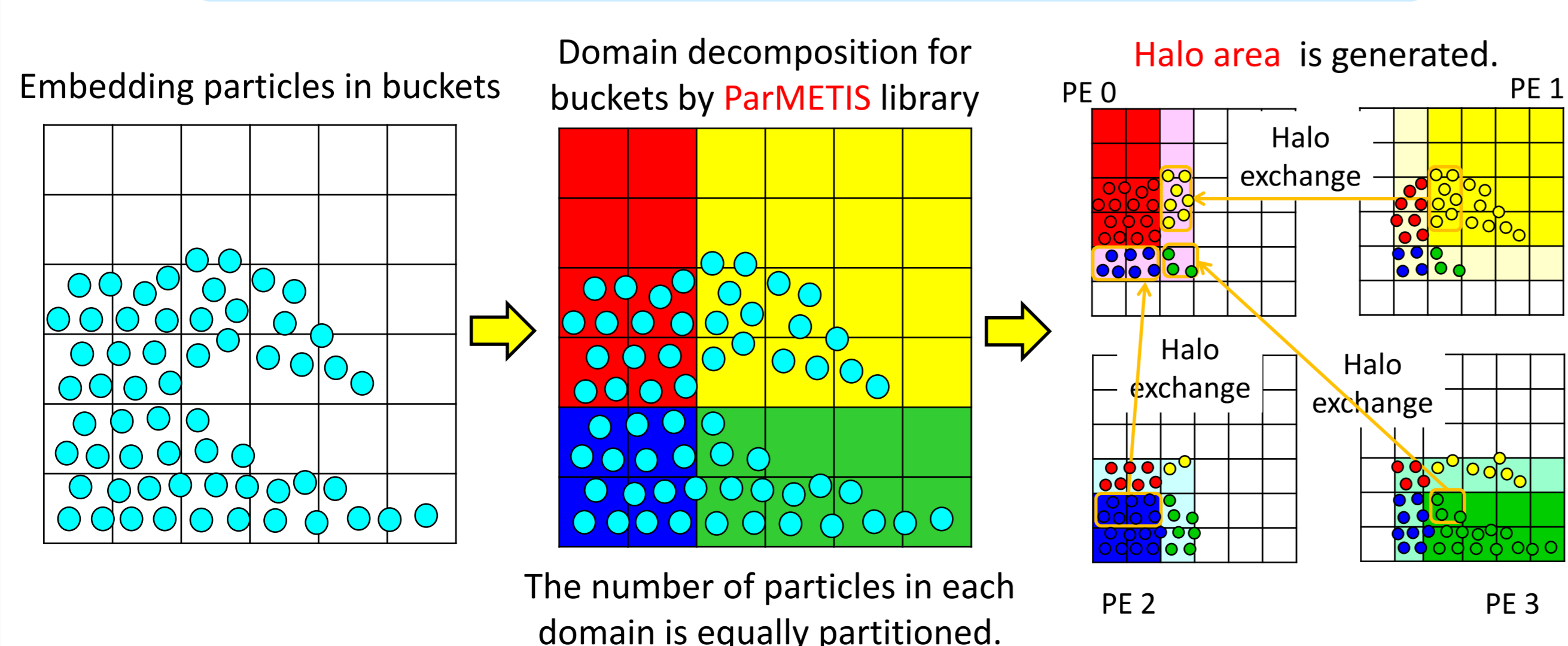
- Particle simulator by particle interaction
  - Moving Particle Simulation (MPS) method
- Corrosion detection among particles using buckets
- Parallel computing
  - Dynamic load balancing by ParMETIS
  - Communication by Halo exchange

- Target problem size
  - 1 million - 10 billion particles
- Development and operating environment
  - OS : UNIX, Linux
  - Compiler : C
  - Communication library : MPI

### Strong scaling of 10 billion particles by K computer



### Domain decomposition and Halo exchange



### Dynamic load balancing

