R&D of common basic library and environment for atmospheric models

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Introduction

* Resolution of atmospheric simulations has been getting higher [illegible]neric models become more [illegible]
  * These require[illegible]
* Computers has[illegible] and more
  * massive p[illegible]
  * heteroge[illegible]
  * relatively slower memory / interconnect / IO

"The Free Lunch is Over!" Sutter (2005)

* Development of models taking account of computer system (architecture, interconnect, system software, etc) is required
  * Collaboration with computer scientists is necessary

* So we started research and development of a new atmospheric model and library for future atmospheric simulations on peta scale or post-peta machines
  * an atmospheric large-eddy simulation (LES) model
  * common basic library and environment for atmospheric modes

Atmospheric LES model (SCALE-LES)

Concept

* Try schemes or methods and test their feasibility for future atmospheric simulations
  * Co-design with computer scientists
* Target is large domain & high resolution simulations (toward future global LES)
  * Making a reference solution to quantitatively validate schemes used today
* Knowledge obtained by development of this model will be included in the common basic library

Model Description

* Dynamics
  * Full explicit (HEVE)
  * spatial differential : the 4th central difference
  * time integration: the 3rd order explicit Runge-Kutta scheme
  * Flux correlation transport (FCT) scheme
* Physics
  * SGS turbulence: Smagorinsky-Lilly type (Brown et al. 1994)
  * Cloud physics: 2-moment 6 category bulk (Seiki and Nakajima 2013), Bin method (Suzuki et al. 2010)
  * Surface turbulence flux: Louise type bulk (Uno et al. 1995)
  * Radiation: MSTRNX (Sekiguchi and Nakajima 2008)

Why “Full Explicit”

* isotropic grid
  * smaller scale turbulence is rather 3D, though larger scale phenomenon are 2D.
  * LES theorem is based on isotropic turbulence
* naïve
* neighbor communication
  * good for parallelization

Current scientific targets

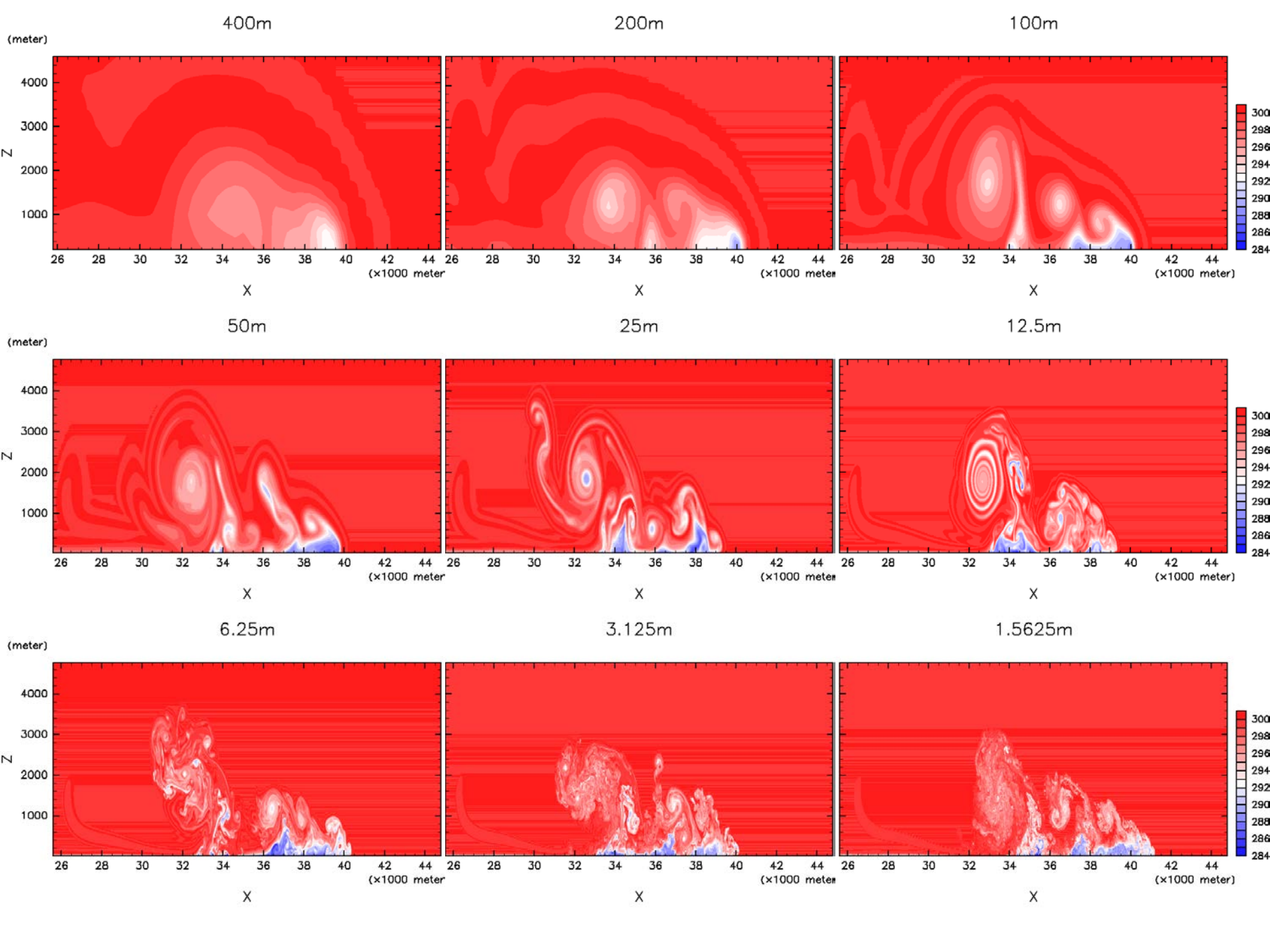
* Stratocumulus
  * transition to cumulus
* Martian planetary boundary layer
  * turbulence
  * dust devil
* Urban heavy rain

Example of experiments

* Gravity current experiment
* Stratocumulus experiment

Gravity current experiment

* a benchmark test (Straka et al. 1993)
  * resolution: 400m - 1.5625m (2D)
  * domain size: 51.2km x 6.4km
  * integration period: 900 sec.
  * no physical viscosity / diffusion (with numerical filter)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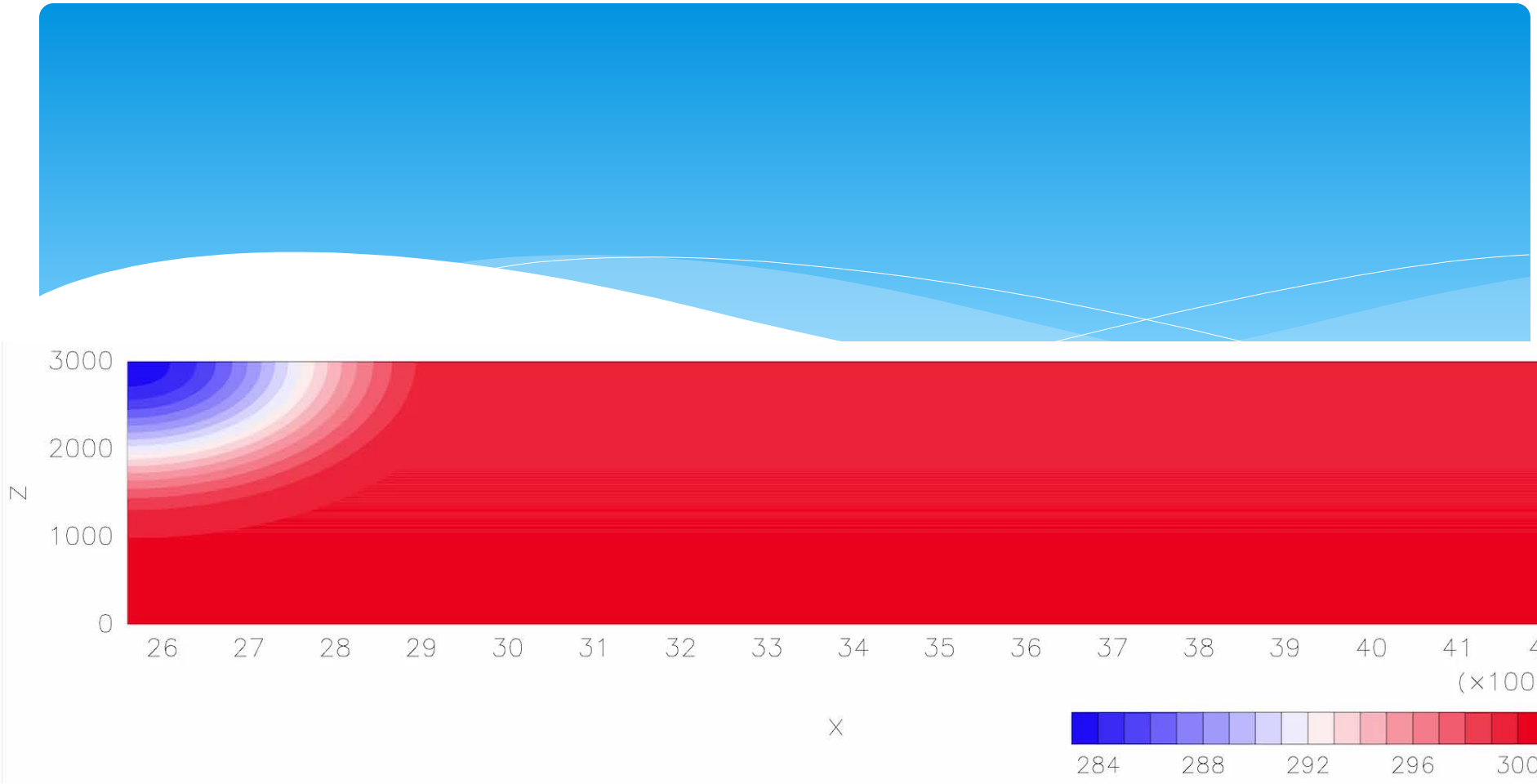
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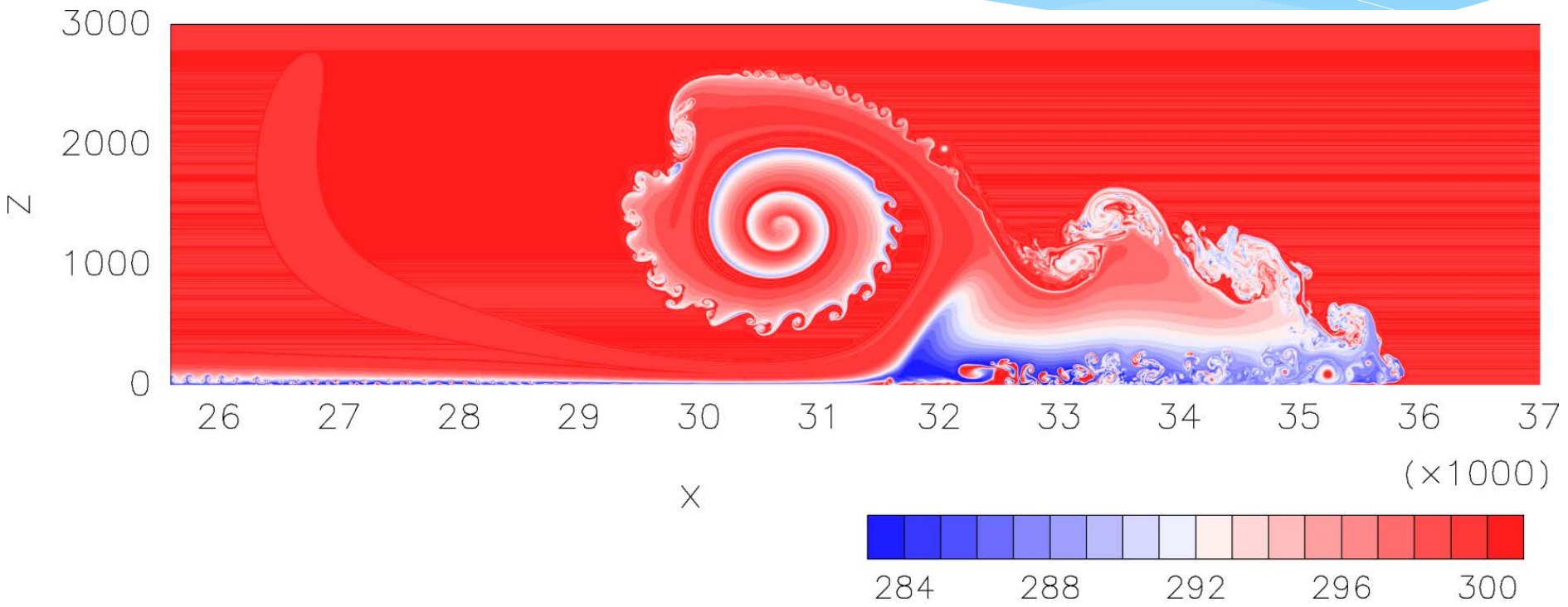
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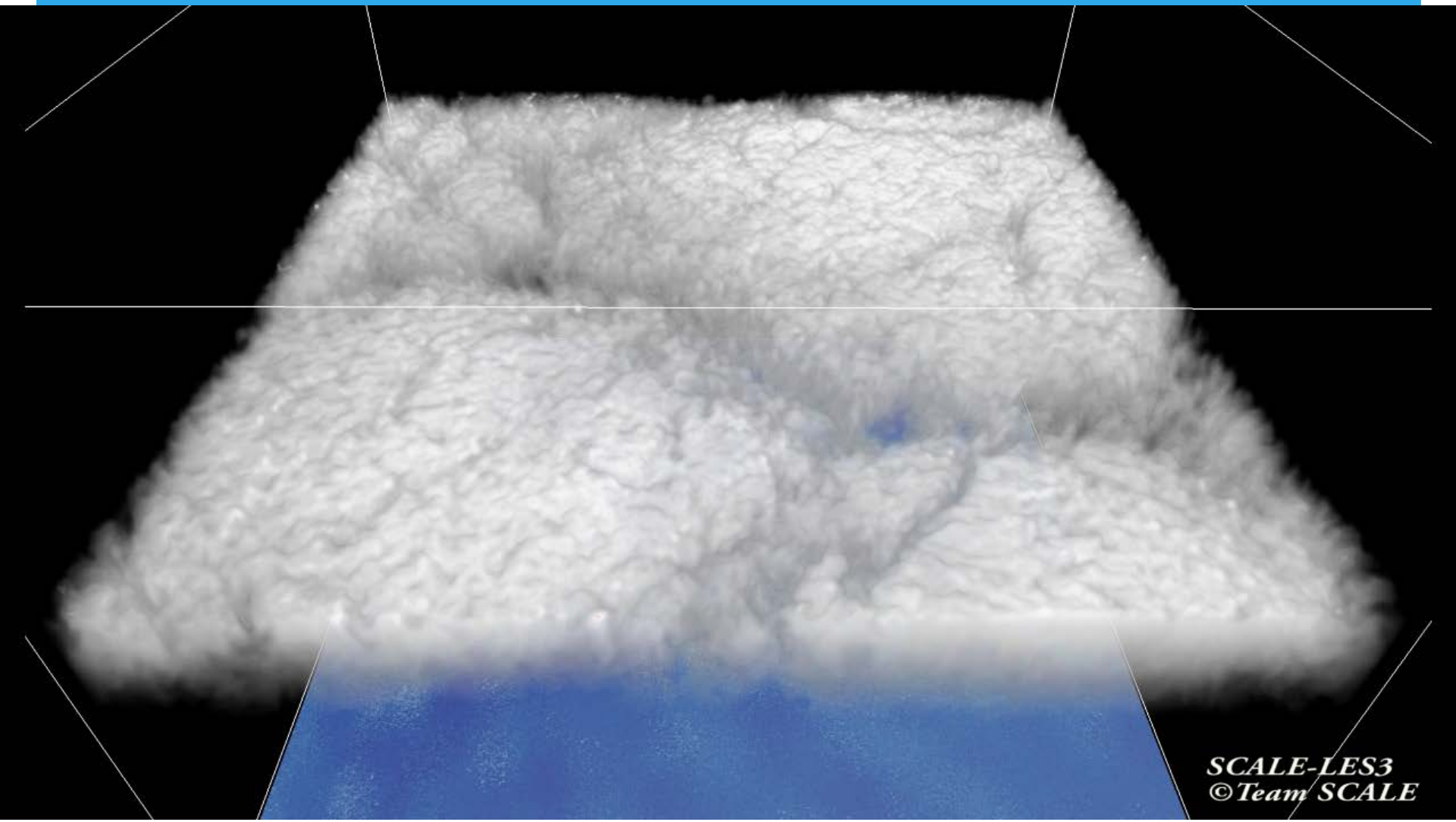
* In 12.5m experiment, the secondary instability is not resolved, and some parameterization to represent smaller eddies, such as eddy viscosity, should introduced
  * coefficient for the eddy viscosity can be estimated from the result of the higher resolution experiment

Stratocumulus experiment

* DYCOMS-II RF01 (Stevens et al. 2005)
  * resolution: 5m x 5m x 5m
  * domain size: 3.36km x 3.36km x 1.5km
  * integration period: 4 hours
  * Cloud physics: 2-momen bulk (Seiki et al. 2013)


SCALE-LES3
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* We are going to extend this simulation to large domain to investigate transition from stratocumulus to cumulus

Validation of current schemes

We try to quantitatively confirm validity of

* non-isotropic grid
  * valid range of aspect ratio ($\Delta x/\Delta z$)
* HEVI (horizontally explicit, vertically implicit)
  * valid range of aspect ratio and time interval (Δt)
* etc

Common Basic Library and Environment

* Difficulty in development of models becomes more serious
  * efficient use of computational resources becomes difficult
  * number of components get increasing
  * each component becomes more sophisticated and complex

* Diversity of atmospheric models is important for soundness of atmospheric numerical study

These require more human / temporal resources

We started an activity to develop a common basic library and environment for atmospheric models

* purpose
  * sharing codes and knowledge between models or groups
    * reducing development costs
  * enabling to switch schemes easily
  * supporting multiple computer architectures
* possible solutions
  * unified API / model structure
    * dynamical and physical processes, IO, utilities
    * coupler
  * documentation
  * standard test cases
  * analysis/visualization tools (parallel capable)
  * domain specific language (should be Fortran user friendly)
  * (introduced knowledge by developing SCALE-LES)

collaborators

* AFES, CReSS, Dennou, GAIA, Jcup, JMA/MRI, MATUSIRO, MIROC, MSSG, NICAM, SCALE (alphabetical order)

at this moment

Summary

* We have developed a LES model and common basic library and environment for future atmospheric simulations
  * SCALE-LES
    * wide & high resolution experiment
    * investigation for future simulation
    * validation of currently used schemes
  * common basic library and environment
    * share codes and knowledge
    * optimized to computer systems