Our model development activity in RIKEN AICS

- introduction of SCALE and SCALE-LES-

S. Nishizawa, H. Yashiro, Y. Sato, T. Yamaura, S. Aadachi, R. Yoshida, H. Tomita and Team SCALE

RIKEN Advanced Institute for Computational Science

Introduction

- Meteorological simulation is *not* a first-principle simulation
  - based on many empirical rules.
    - tones of tunable switches
  - Validity of simulations can be hardly confirmed especially
    - for paleo/future climate, or other planets
    - with higher resolution

Comparison plays important role for reliability of models.
Diversity of meteorological models is really important.

- Meteorological simulation models are getting complex more and more.
  - Each process is more sophisticated
  - Number of included processes have become increasing
  - Programing code have become complex due to complex computer systems

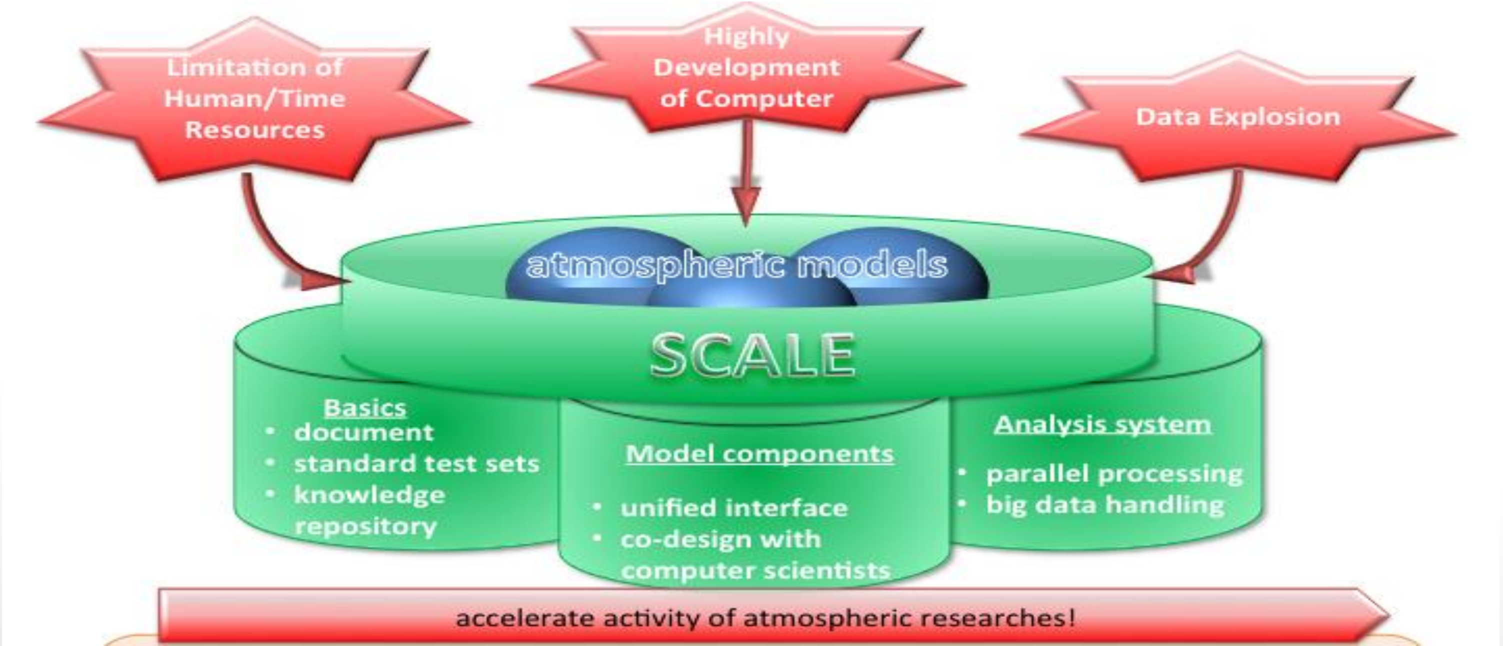
Limitation of human and temporal resources is serious

- As a possible solution of the problems, we have develop a framework (library and environment) to develop models.
  - for model developers
  - Meteorological scientists could focus on physical performance
  - Computational issues are mainly handled by the framework
  - unify APIs
    - switching schemes or exchange schemes between models could become easier
    - comparison could become easier

SCALE

SCALE (Scalable Computing for Advanced Library and Environment)

- from x86 PCs to next generation super computers
- Collaborate with computer scientists
- Open source with the 2 clause BSD license
  - http://scale.aics.riken.jp/



- Components
  - model components (unified API)
    - dynamical cores: HE-VE, HE-VI, HI-VI
    - physics: microphysics, turbulence, radiation, surface flux
    - misc: I/O, communication, logger, timer etc
  - documents
    - model description
    - knowledge repository (future work)
  - test cases
    - component unit test
    - standard benchmarks
  - pre- and post-processing tools (future work)
    - parallel handling

We started to collaborate with other model developer groups (JMA/MRI, MIROC, NICAM, CReSS, AFES, MSSG, GAIA, MATSIRO, DENNOU)

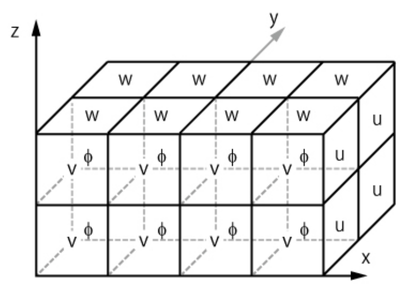
SCALE-LES

A meteorological Large-Eddy simulation model using SCALE

- An application of SCALE
- To perform wide domain and high resolution simulation
  - O(10-100)km^2 domain with O(10-100)m resolution; mesoscale LES

SCALE-LES model description

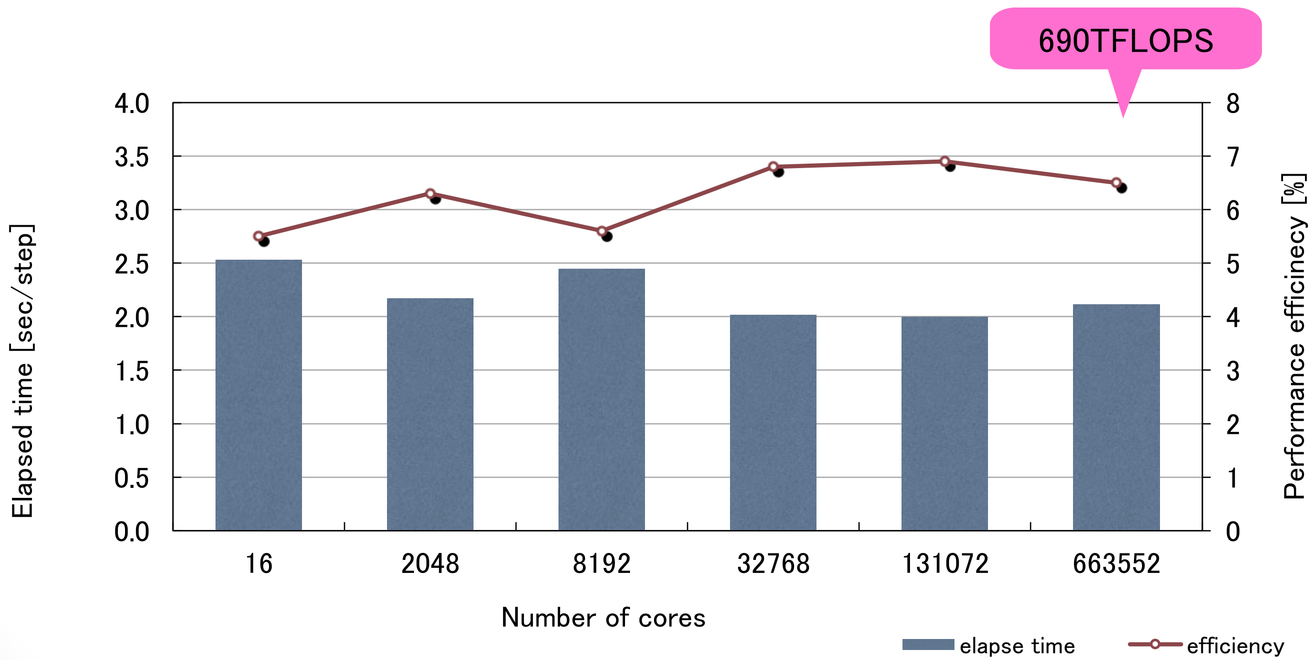
- Prognostic variables:
  - density, momentums, mass-weighted potential temperature, mass concentration of tracers
- Dynamical core:
  - governing equation: fully compressive equation
  - temporal integration:
    - full explicit (HE-VE) and implicit (HE-VI, HI-VI) schemes
    - 3 steps RK scheme
  - spatial difference:
    - 4th order central difference for advection
    - 2nd order central difference for terms related with acoustic wave
  - grid : Arakawa-C grid
  - topography: terrain following, thin wall (testing)
  - tracer advection: CWC + FCT
  - numerical filter: 4th or 8th order hyper diffusion



- Physical processes
  - Microphysics
    - single moment 3 category bulk (Kessler 1969)
    - single moment 6 category bulk (Tomita 2008)
    - double moment 6 category bulk (Seiki and Nakajima 2014)
    - bin (Suzuki et al. 2010)
    - super droplet (Shima 2009; testing)
  - Turbulence
    - Smagorinsky-Lilly type SGS turbulence
    - Mellar-Yamada Nakanishi-Nino level 2.5 (Nakanishi and Niino 2009)
  - Radiation
    - MstrnX (Sekiguchi and Nakajima 2008)
  - Surface flux
    - Louise type (Uno et al. 1995)
    - Beljaars (1994)
  - Land model
    - multilayer becket model
  - Urban canopy
    - single layer canopy (Kusaka 2010)

computational performance

- performance @ K computer
  - above 10% of peak performance (dynamical core)
    - 5~8% for whole simulation (including I/O)
  - about 100% weak scaling to full system (663,552 cores)

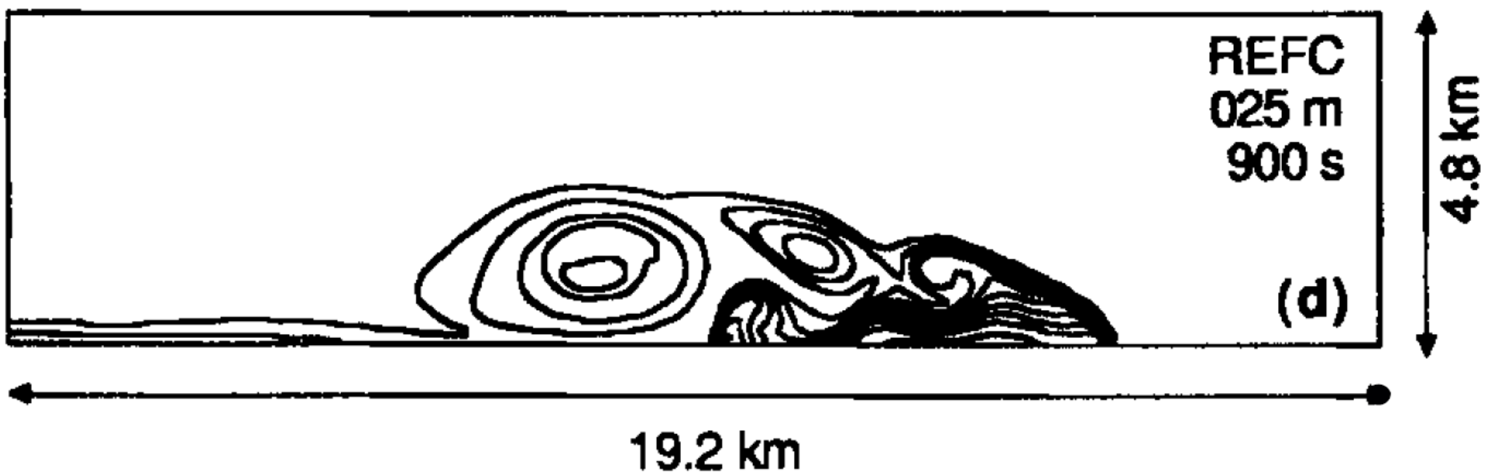


- For efficient development
  - Using git for version controlling
  - Using redmine for project management
  - Using CI for early finding bugs
    - Run all the tests at each commit automatically

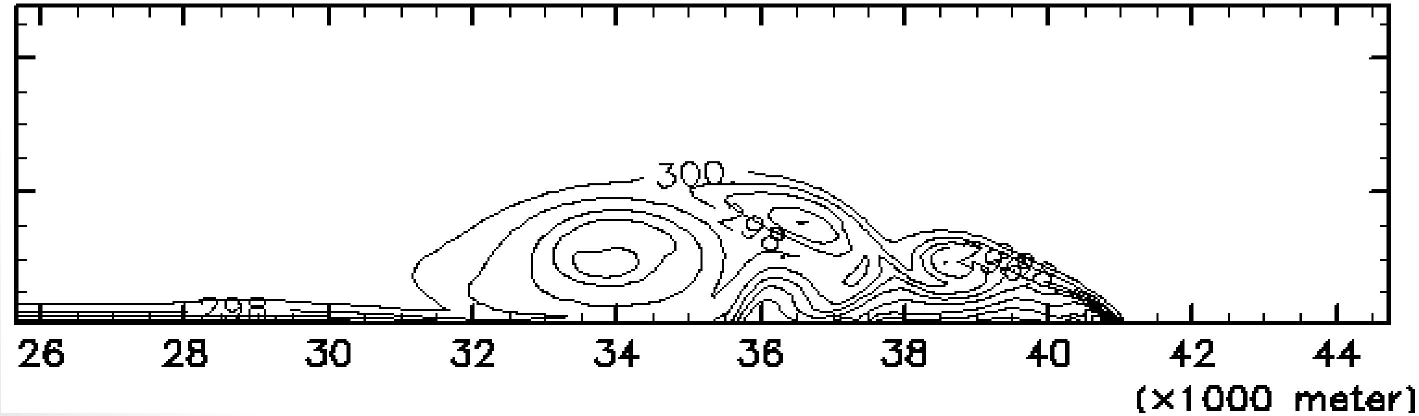
Dynamical core test

- Density current test case (Straka et al. 1993)

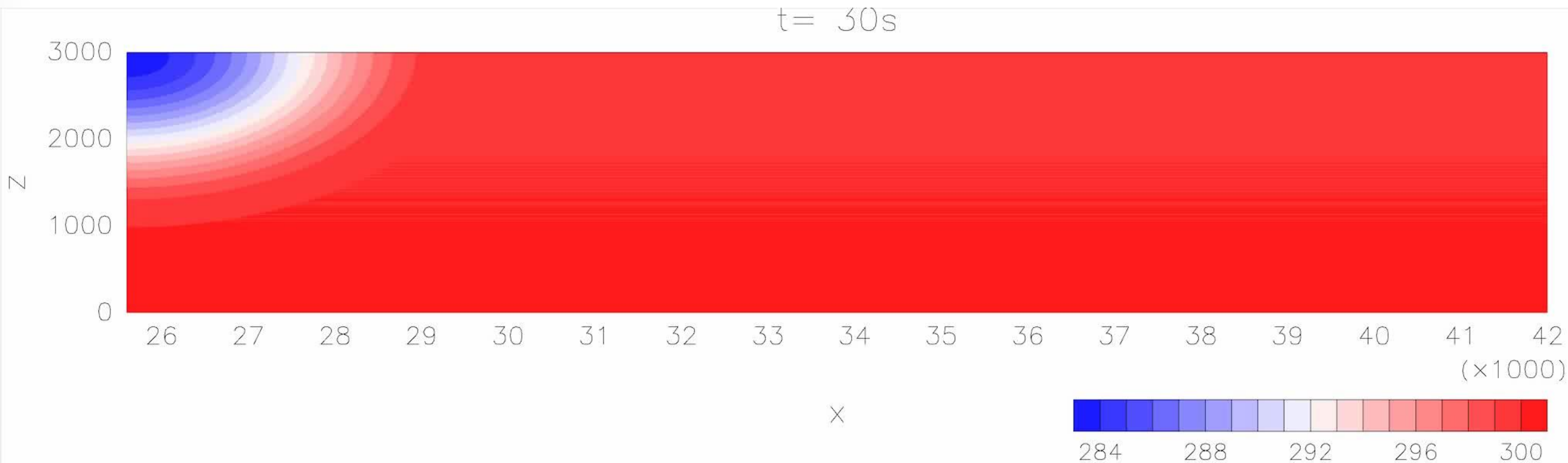
Straka et al. (1993)

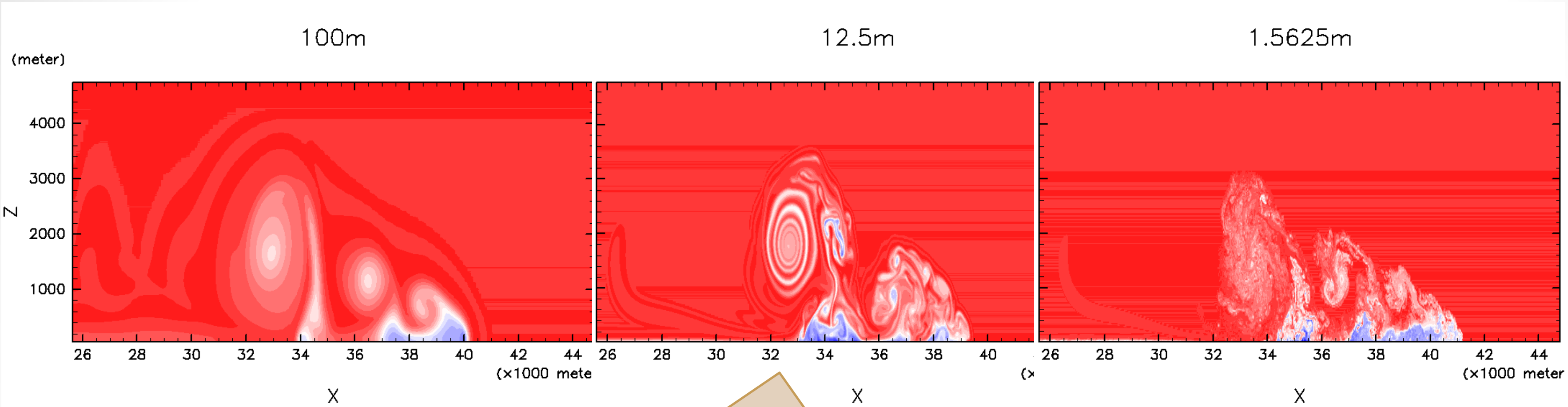


SCALE-LES (100m resolution)



- density current without physical diffusion/viscosity
  - but with numerical diffusion
- 51.2 km x 6.4 km 2-D domain
- 1.5625 m resolution (134M grids)
- 900 sec integration





The bigger spiral structure still remain
due to absent of the smaller scale instability.
It does not mixed well.

This implies that

higher resolution experiment is not always better than lower one without appropriate treatment (parameterization).

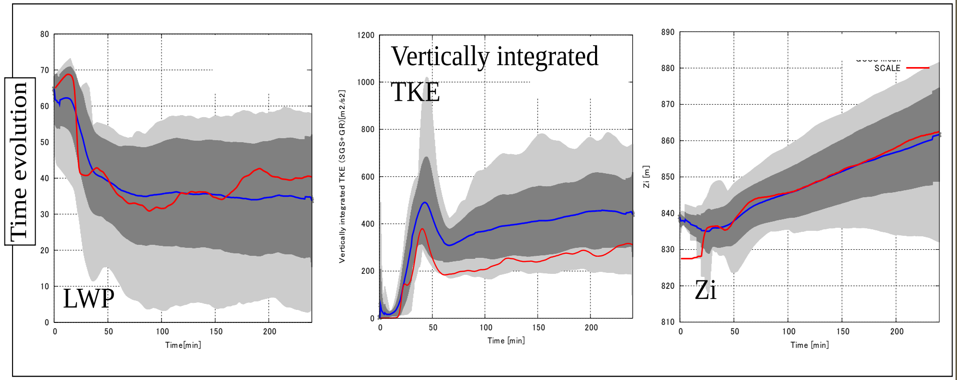
Cloud microphysics and turbulence test

DYCOMS-II RF01 case (Stratocumulus without rain)

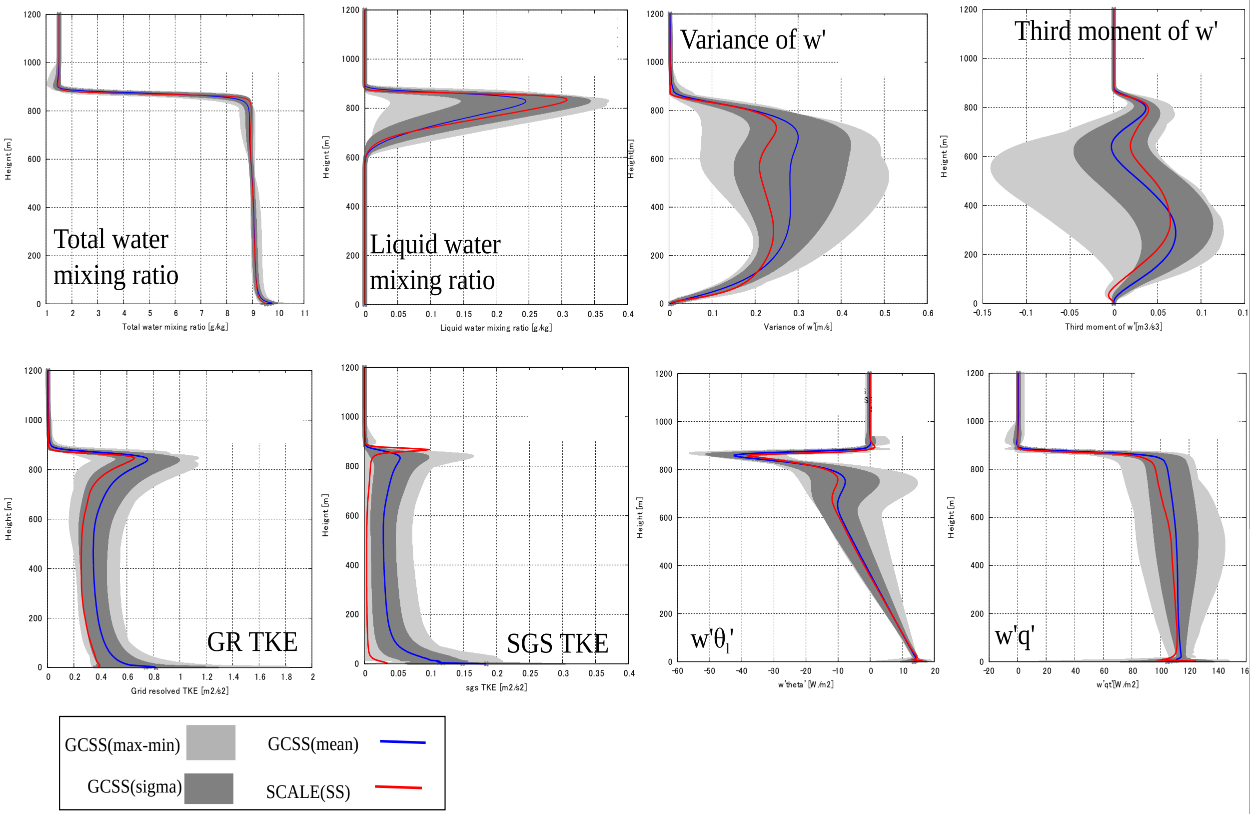
Experimental setup is based on Stevens et al. (2005)

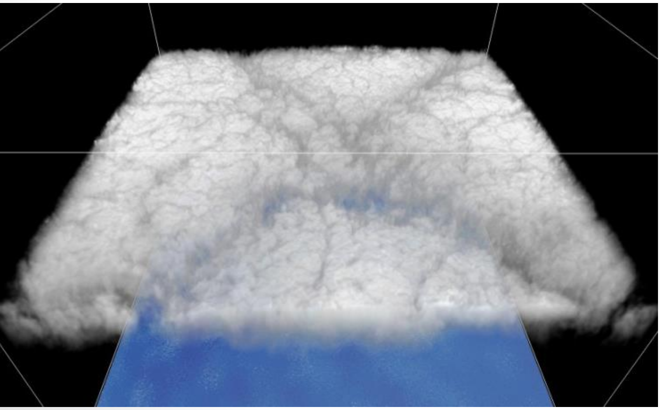
- Domain size: 3.36km x 3.36km x 1.5 km(3D)
- Resolution: dx=dy=35, dz=5m
- Calculation time : 4 hour (dt=0.006s)
- Cloud physics : 2-moment bulk [without rain and sedimentation]
- Radiation : Parameterization of Stevens et al. (2005)
- Surface flux : Constant value

Temporal evolution



Hourly averaged profile (last 1 hour)





Mixing ratio of water contents.

Current science targets with SCALE-LES

- Shallow clouds
  - open/close stratocumulus
- Very short range heavy rain forecast in Kansai (talk by Dr. Miyoshi)
  - big data assimilation
- Future heavy rainfall in Kobe/Hyogo
- Martian planetary boundary layer

Summary

- Develop a framework for meteorological model development
  - Meteorologists could focus on physical performance against complex future computer systems.
  - We try to achieve well computational performance by R&D with computer scientists.
  - Collaboration with other model developing groups would be enhanced.
- Wide-domain high-resolution simulations (mesoscale LES)
  - SCALE-LES is developed as an application of SCALE.
  - Mesoscale LESs are now in progress.
    - For future global LES (with icosahedral grid system)