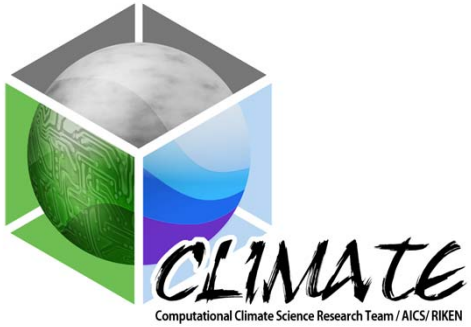
Numerical simulations of shallow clouds by SCALE-LES3

⇩

Development of SCALE-LES3 (SCALE-LES ver. 3) and benchmark tests

Yousuke Sato, Seiya Nishizawa,
Hisashi Yashiro, Yoshiaki Miyamoto,
Hirofumi Tomita, and Team-SCALE



1:What is SCALE-LES?

SCALE

（Scalable Computing for Advanced Library and Environment）

Library for weather/climate research for peta-scale or post peta-scale computer

Develop team in RIKEN AICS

Weather/climate team

Computational science team

Computational Climate Science Research Team	System Software Research Team	Programming Environment Research Team	HPC Programing Framework Research Team	HPC Usability Research Team

Co-design with researchers of computational scicnce

Performance

about 10% of peak FLOPS @K computer

99.9% of weak scaling

SCALE member

H. Tomita

S. Nishizawa

H. Yashiro

Y. Miyamoto

Y. Sato

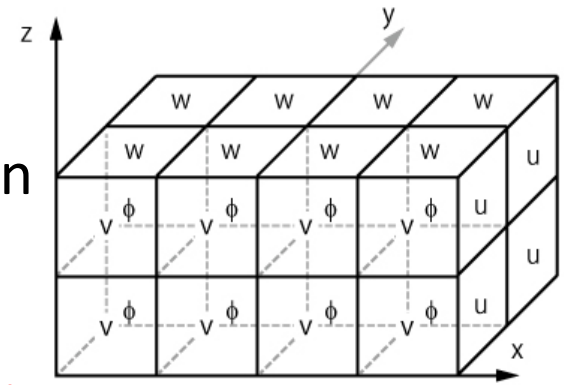
2. Model: numerical method

SCALE-LES

- Fluid system : 3D fully compressible
- Numerical solving method

Grid system	Arakawa-C
Temporal descretization	3rd order Runge-Kutta (HE-VE)
Advection for momentum	4th order
Advection for ρθ	4th order
Pressure gradient force	2nd order central
Numerical diffusion	4th order

Schematic illustration of grid system



- Included component
  - SGS model: Smagorinsky-Lilly
  - Cloud physics: 2-moment bulk, 1-moment Bin
  - Radiation: MXTRN-X
  - Surface flux : Monin-Obukhov's similarity

Benchmark tests are mostly finished and first version will published soon

3. Benchmark test

- Cold bubble (S. Nishizawa)
  - Test of dynamical frame : only dynamics module
- Dry turbulence (S. Nishizawa and Y. Miyamoto)
  - Test of dynamical core and sub-grid model : dynamics + SGS
- DYCOMS-II RF01 (Stratocumulus) (Y.Sato)
  - Test of SGS and cloud physics without rain
- RICO (Shallow cumulus) (Y.Sato)
  - Test of cloud physics with rain

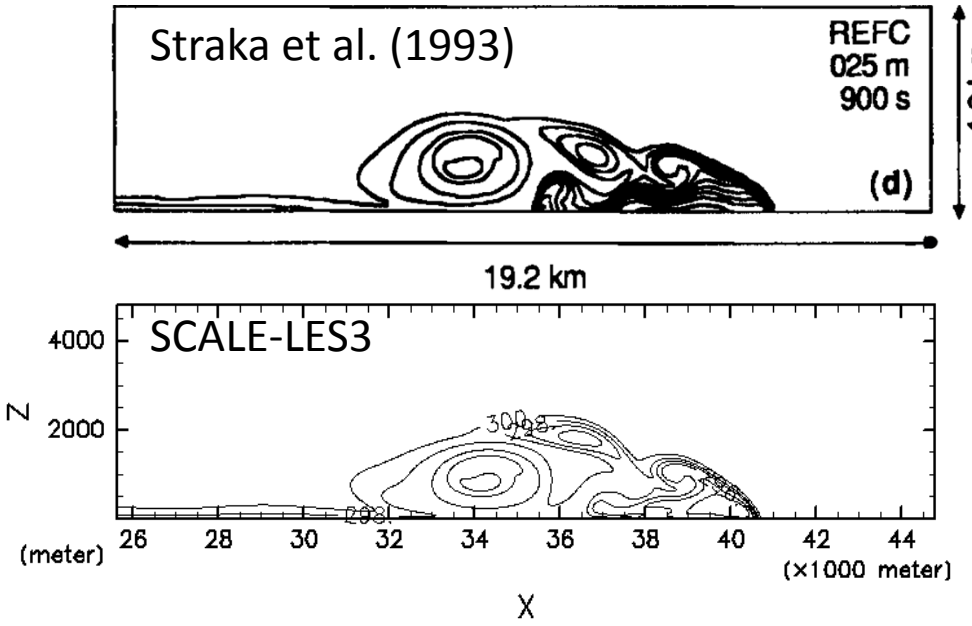
Cold-bubble Experiment

(Nishizawa et al. in preparation)

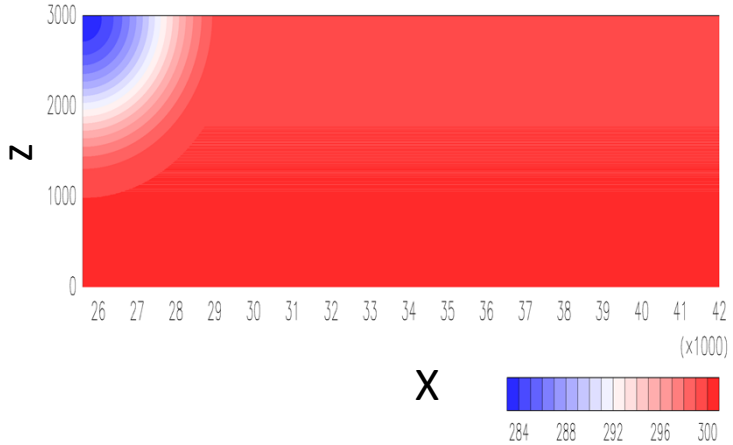
Experimental setup is based on Straka et al. (1993)

- Dynamical core only
- Domain size: 51.2km x 6.4km (2D)
- Resolution: 25m
- Cold bubble: -15 K (max)
  - location : x=25.6km, z=3km
  - size :4km x 2km
- No diffusion except for numerical diffusion 10^{-3}

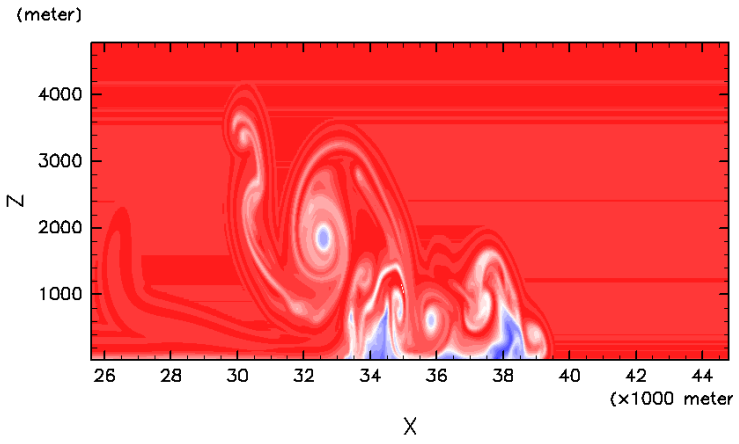
Deviation of θ from mean value at t =900s



Potential temperature at initial time



25m



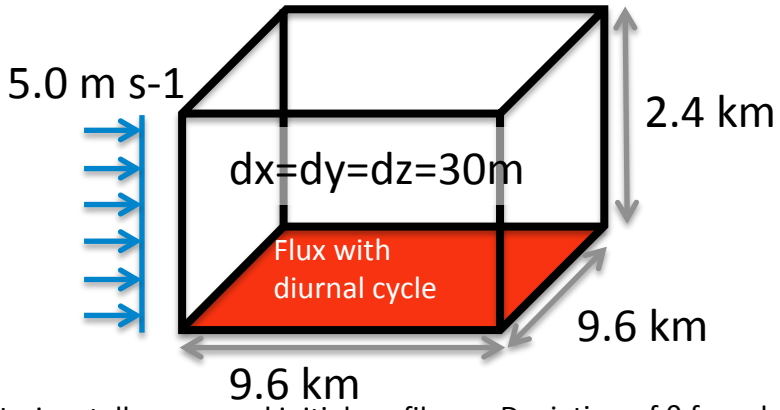
(Nishizawa et al. 2013 in preparation)

Dry turbulence

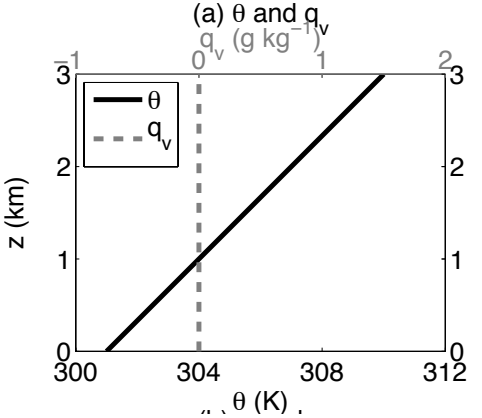
(Miyamoto et al. 2012)

Experimental setup is Exactly same as Tanaka et al. (2008)

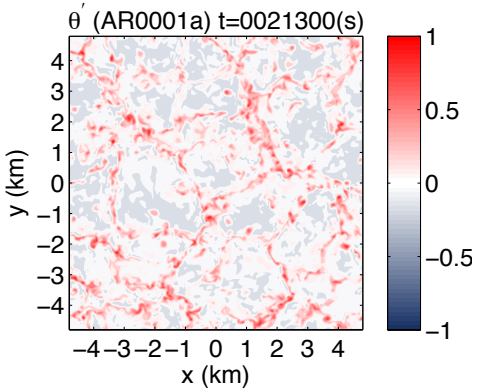
Calculation time : 6 hour (dt=0.03s)



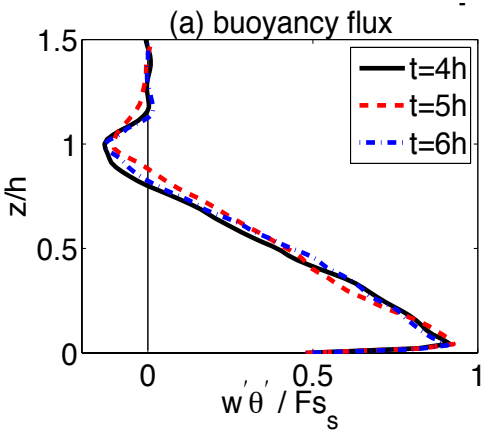
Horizontally averaged initial profile

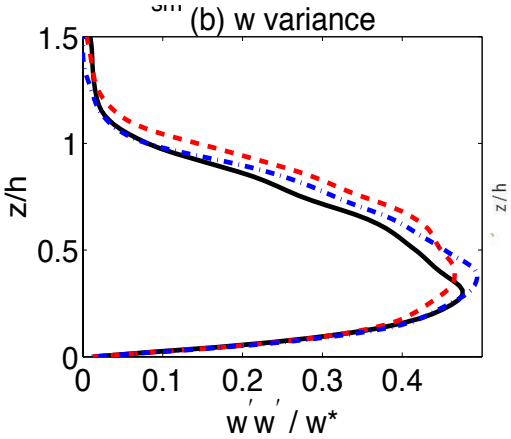


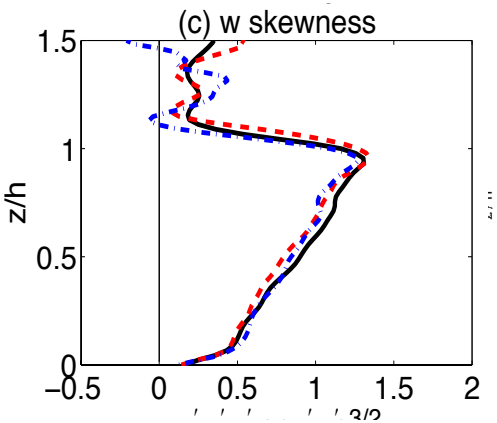
Deviation of θ from horizontal average at t=21300 [s]



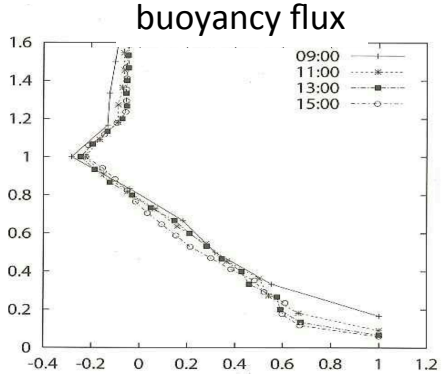
SCALE

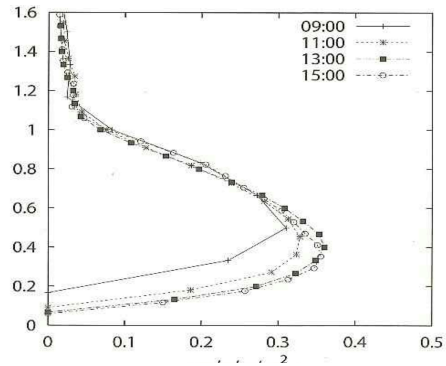


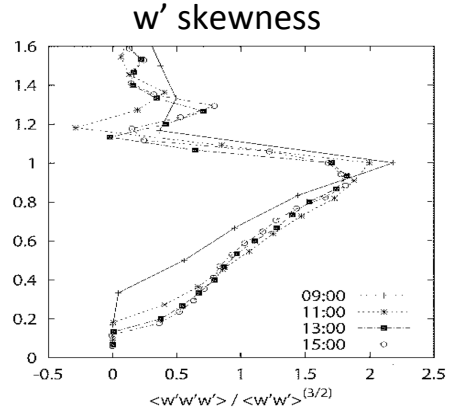




Tanaka et al. (2008)





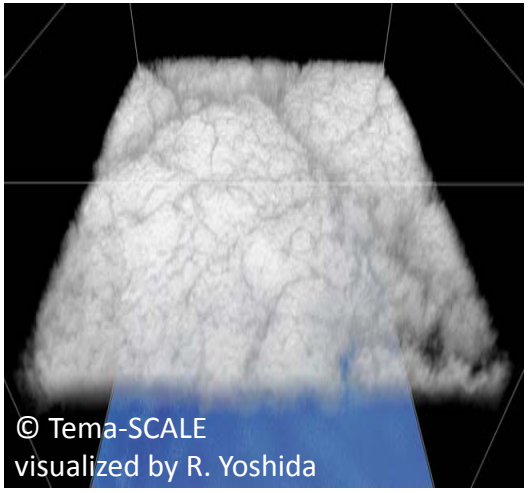


DYCOMS-II RF01 case (Stratocumulus without rain)

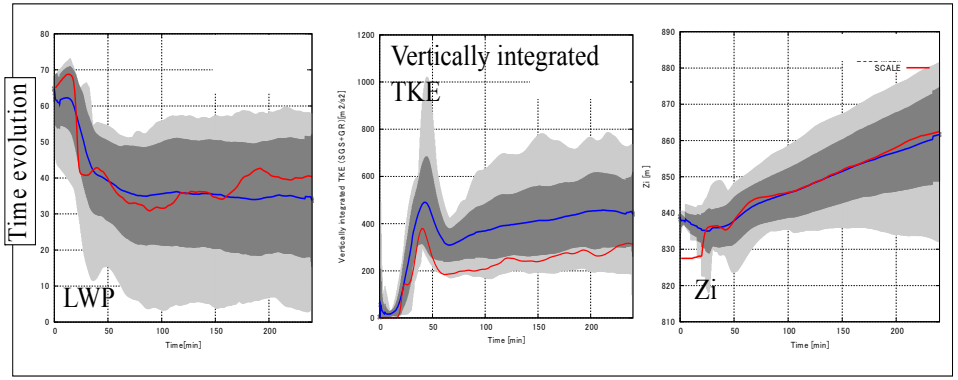
Experimental setup is based on Stevens et al. (2005)

- 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 (Seiki and Nakajima, 2013) [without rain and sedimentation]
- Radiation : Parameterization of Stevens et al. (2005)
- Surface flux : Constant value
- Numerical diffusion : 10^{-6}

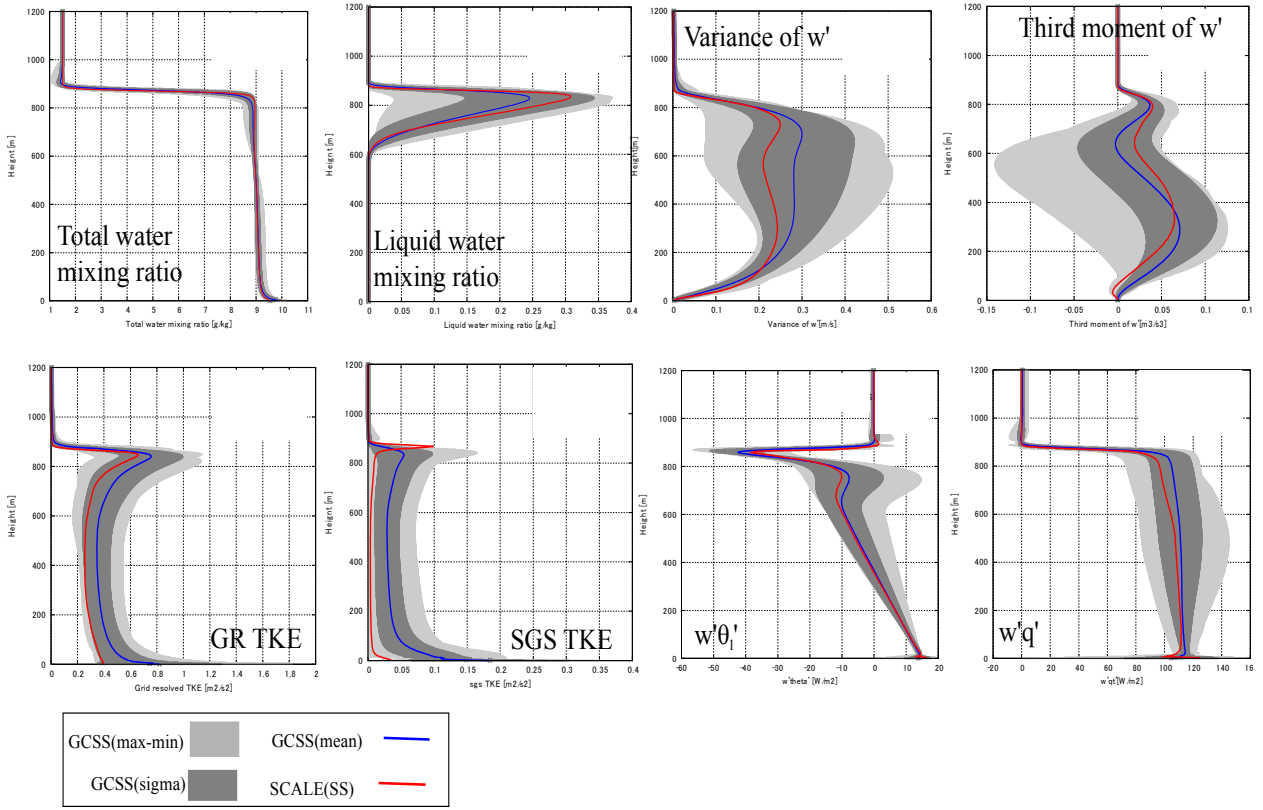
Cloud water mixing ratio at t=3.5h



Time evolution



Hourly averaged profile (last 1 hour)



Summary

- SCALE-LES ver. 3.1 is now developing at RIKEN AICS
- Several benchmark tests indicate that SCALE-LES 3.1 shows good performance

Announce

- The SCALE-LES ver. 3.1 will published from Web site of RIKEN soon.
- **All of you can use the SCALE-LES by free (BSD 2 license)**

Using K computer of Exa-SCALE computer, experiments with extremely fine grid spacing will be conducted. ⇒ Sensitivity experiment of grid spacing is required before product run!!

4: Sensitivity of grid spacing and aspect ratio of grid

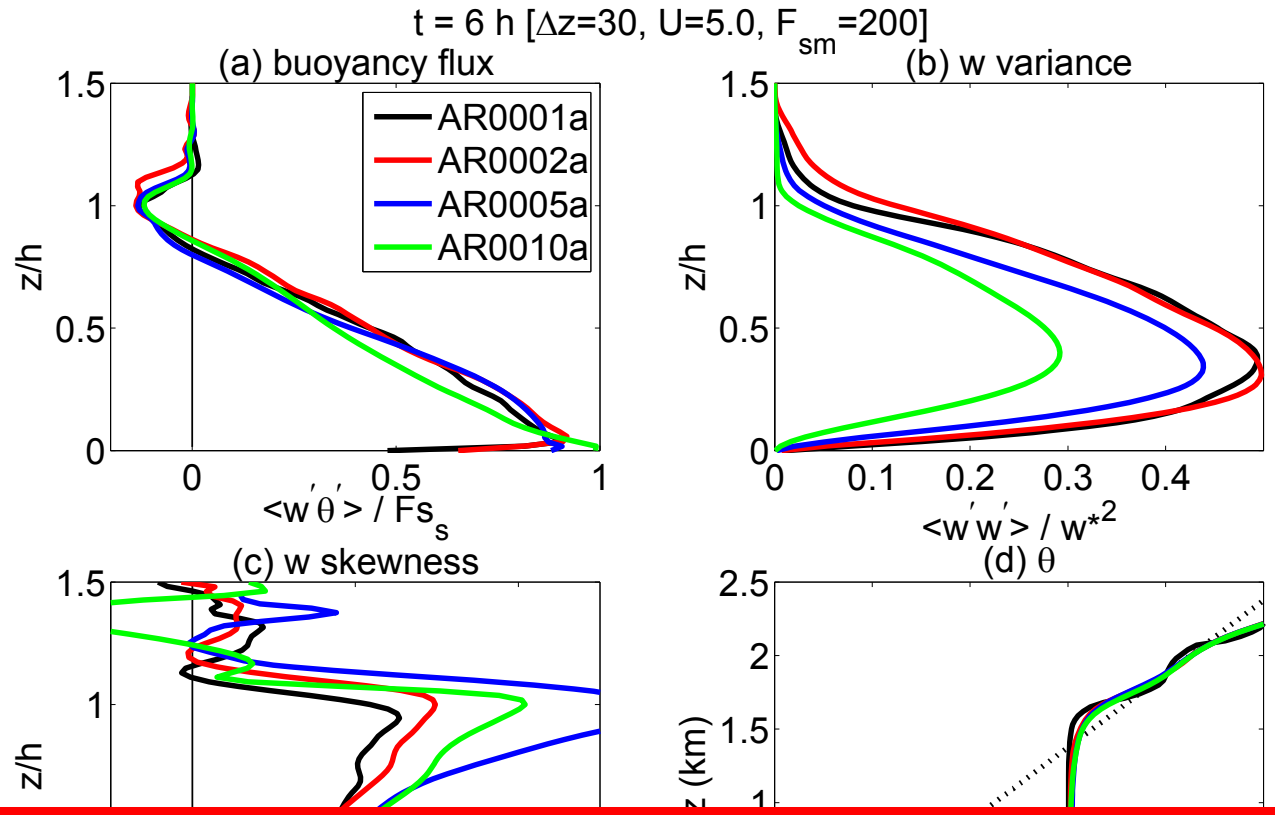
- Cold bubble
- Dry Turbulence
- RF01

From now the detailed description will be skipped because of time limitation….

If you have any question, please contact me after this session!!
The detailed discussion will be shown at JMS Spring meeting by S. Nishizawa (D403), and Y.Sato (B460)

Dry turbulence

Experiments	Δ x (m)	Δ z (m)	# of horizontal grid	# of vertical grid	grid aspect ratio
AR0001a	30	30	320	80	1
AR0002a	60	30	160	80	2
AR0005a	150	30	64	80	5
AR0010a	300	30	32	80	10



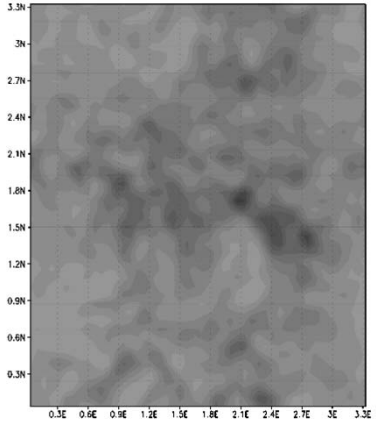
AR=5,10: w’ w’ and w’ w’ w’ are different from those in AR=1,2
=> the turbulent fields are different from that which should be simulated in the current setting

Stratocumulus (RF01)

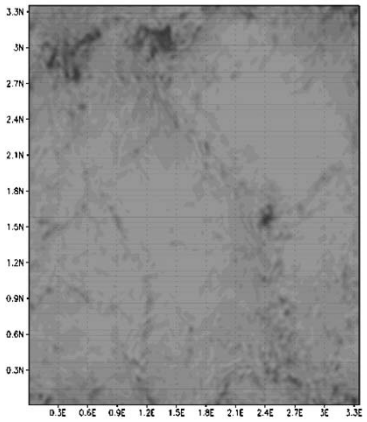
dz＼dx	70m	35m	15m	5m
5m	14 (H70V5)	7(H35V5)	3(H15V5)	1(H5V5)

Red line : GCSS mean
Shade :GCSS range

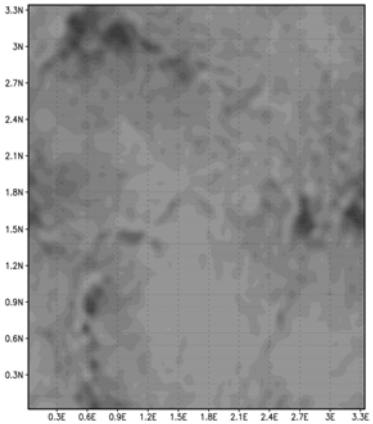
AR14 (H70V5)



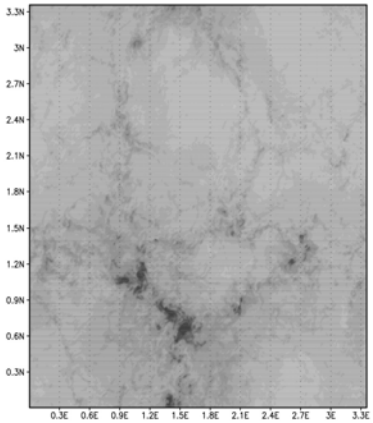
AR3(H15V5)

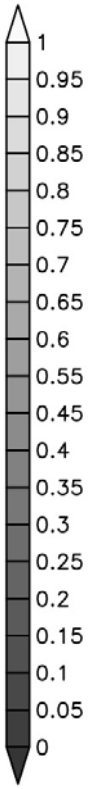


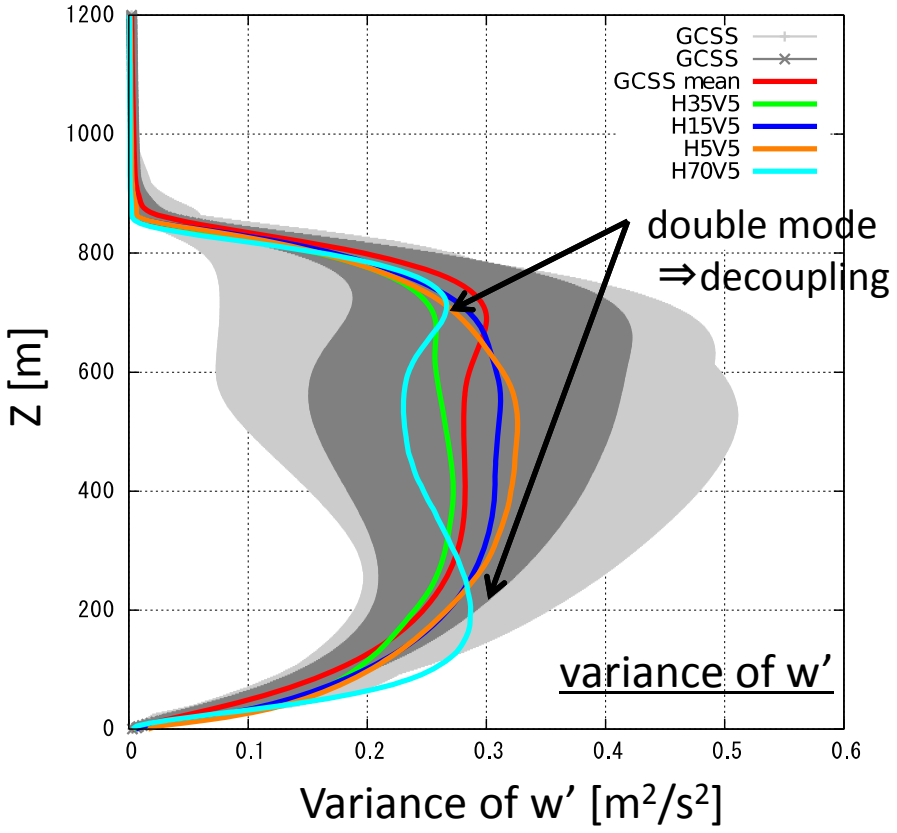
AR7(H35V5)



AR1(H5V5)







Decoupling should not occur from observation
⇒ Aspect ratio = 3 (dx=15m, dz=5m) is required!

Summary

- SCALE-LES ver. 3.1 is now developing at RIKEN AICS
- Several benchmark tests indicate that SCALE-LES 3.1 shows good performance
- Aspect ratio should be set to 1～3
- The SCALE-LES ver. 3.1 will published from Web site of RIKEN near future.
- All of you can use the SCALE-LES by free (BSD 2 license)
- Effect of grid spacing is now investigating and detailed discussion will be published at JMS Spring meeting!