8. Computational Climate Science Research Team

8.1. Team members

Hirofumi Tomita (Team Leader)
Shin-ichi Iga (Research Scientist)
Yoshiaki Miyamoto (Postdoctoral Researcher)
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Hisashi Yashiro (Postdoctoral Researcher)[1]
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1: joined us from the October in 2011

2: joined us from the September 2011 as a member of G8 Research Councils Initiative "ICOMEX"

8.2. Research Activities

In climate research area, the simulation has become one of the most vital technique as well as theory and observation. Since the IPCC started to report environmental assessment in 1990s and tackled to the global warming issue, many climate projections by various climate models have been performed. However, from restrictions of computer resources, the reliability issue of models still remains and the climate model do not become in the mature stage now.

In this research team, a pioneering research, which suggests the direction of future climate simulation, will be conducted. In order to raise the reliability of climate model more than the current status, we aims to construct a climate model based on more theoretically physical principles.

Such a model needs tremendously large computer resources. Therefore, it is necessary to design the model to pull out the capability of computers as much as possible. Recent development of supercomputers has a remarkable progress, however, new numerical techniques may be needed under the collaboration of hardware research and software engineering for effective use of them on the future HPC, including K computer.

For the above research achievement, our team is cooperating with the computational scientists in other fields and computer scientists. We enhance the research and development including effective techniques and make a next-generation climate model. Now, establishment of the above basic and infrastructure research on K Computer is required. This kind of research also leads to post K computer or subsequent ones.

In order to archive the team mission above, we have started three projects in this fiscal year:

1) Construction of a new library for climate study:

   We have proposed the subject "Estimation of different results by many numerical techniques and their combination" as a synergetic research to MEXT in the last autumn during the discussion with the Strategic 5 fields. In this project, our team committed the provision of numerical libraries for climate study and other related fields, which contribute to K users.

2) Feasibility study of Exa-scale computing using the general circulation model:
The project of G8 Research Councils Initiative "ICOMEX" has been started from the last autumn. Through this project, a part of our team does the feasibility study of Exa-scale computing by the global cloud resolving model.

3) Grand challenge run for sub-km horizontal resolution run by global cloud-resolving model:
A part of our team commits the contribution to the 3rd Strategic Field Project. In this project, the global cloud resolving model NICAM is a main simulation code. Especially, we are responsible to get high computational performance on K computer.

8.3. Research Results and Achievements

8.3.1. A new library for climate study on K computer

In FY2011, we conducted a feasibility study how efficiently the current numerical schemes do run on the K computer. For this purpose, we have organized a new multi-disciplinary team "Team SCALE" with computer scientists in AICS. Through this activity, we developed a new meteorological program code, which targets to K computer and also directs to the future meteorological science. This program is a kind of Large Eddy Simulation (LES) code. Since the required resolution is much higher than Cloud-Resolving Model (CRM), the adaptation of such a technique is still limited to a narrow domain. However, once Peta-scale computers such as K computer are available, the technique will be more popular in the wider domain. In addition, it is very useful to develop the LES code on K computer not only for the meteorological field but also for other fields in which their research are achieved by the computational fluid dynamics.

For the meteorological application, the time integration method has a wide variety; full explicit scheme, full implicit scheme, and horizontally explicit and vertically implicit scheme. We started to compare the various time integration methods. First, we employed the full explicit scheme, because it gives a physical and computational reference solution. Figure 1 shows a snapshot result from the planetary boundary layer test case. Comparing with the results published already, we checked that our result has a reasonable statistics for the atmospheric turbulence.

For the microphysics, the single moment bulk method by the Kessler(1969) and a double moment bulk method developed by Seiki and Nakajima (2012) are implemented. Table 1 gives a typical computational performance on K computer. In this table, we show the elapse time. The sustained performance is over 10% in the dynamical part. Figure 2 shows the scalability up to 24576 nodes. This code has a reasonable weak-scaling.

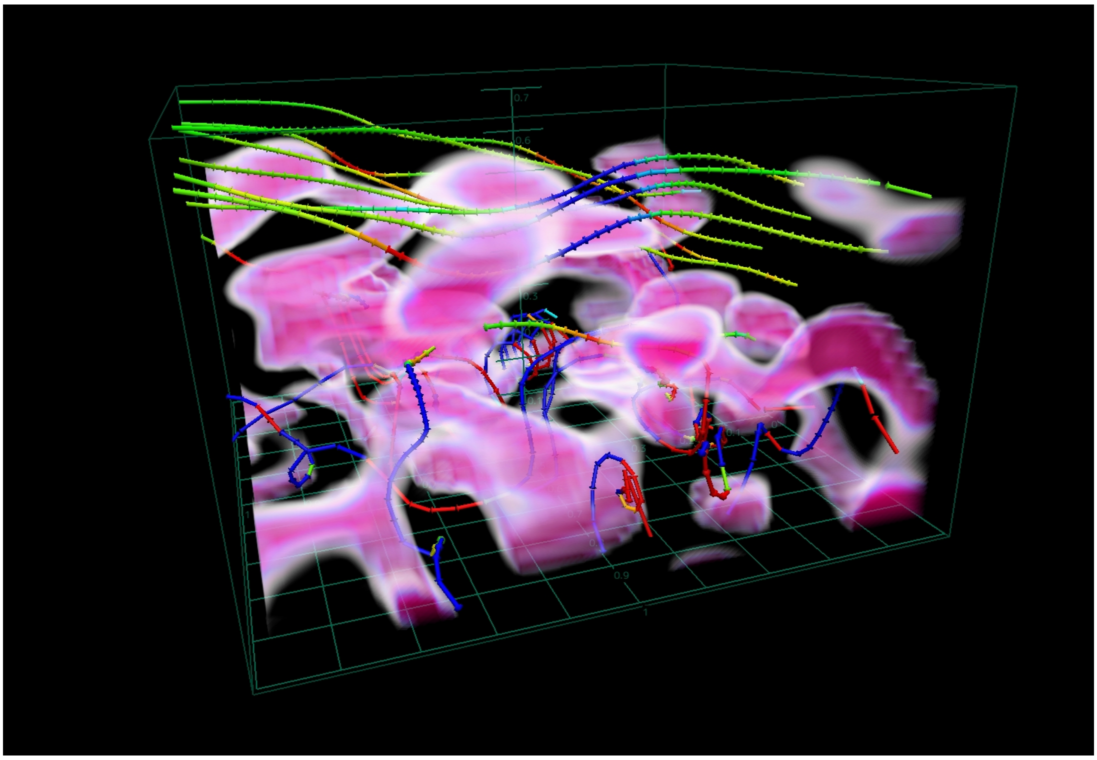

Figure 1. A snapshot of planetary boundary layer simulation with the 25m isotropic resolution. The isosurface and vector indicates the anomaly of potential temperature form the environment and velocity vector, respectively.

Table 1. Computational performance of SCALE-LES: The array size and time step are (kmax,imax,jmax)=(1256,32,32) and tmax = 300, respectively. The CTL is the case without turbulence(TB) and microphysics schemes (MP). RDMA is the case that uses RDMA functions directly in the communication. w/kessler and w/NDW6 are the cases with cloud microphysics of single and double moment bulk scheme.

[sec]	CTL	RDMA	w/ Kessler	w/ NDW6 orig	w/ NDW6 tuning
Main loop	110.6	102.5	112.7	124.9	116.3
Dynamics	109.5	101.5	108.7	108.7	108.7
TB	0.0	0.0	0.8	1.0	0.9
MP	0.0	0.0	1.6	13.7	5.4
COMM	15.9	4.7	15.7	15.7	15.7

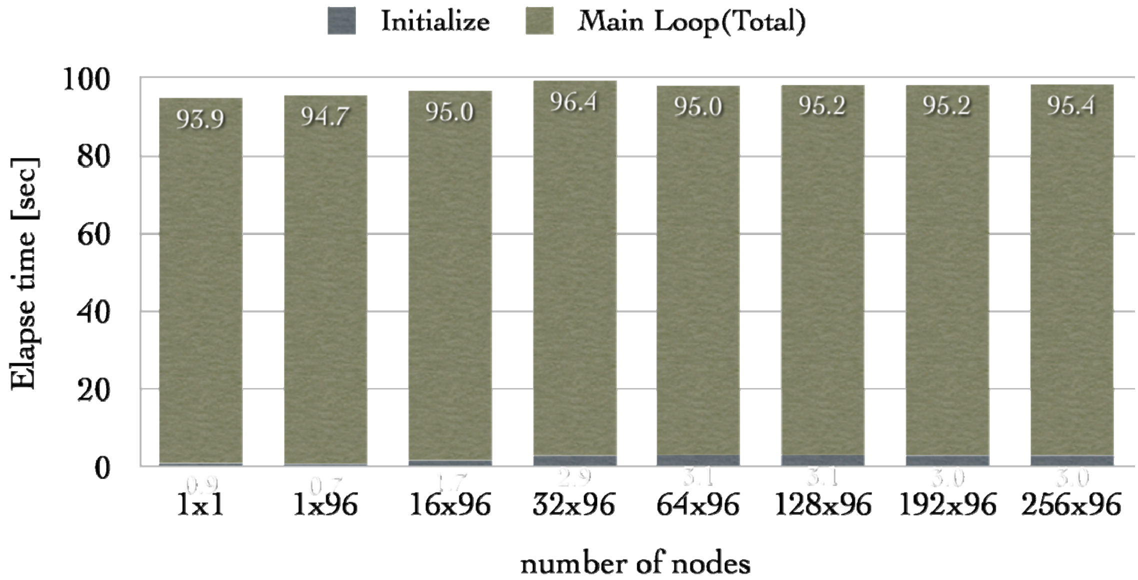

Figure 2. The scalability (weak-scaling) of SCALE-LES on K Computer.

8.3.2. ICOMEX project

This project is, especially, focusing on the computational efficiency and possibility of popular icosahedral models, NICAM, ICON, and MPAS. Since the kick-off meeting on the October 2011, we have been concentrating to prepare the environment for model inter-comparison.

As the first step, we have compared the physical results from NICAM and ICON. Figure 3 shows the results of Held & Suarez Test Case for both of models. As a first step, the reasonable results are obtained. For example, the intensity of jet decrease with increase of resolution, the cold region in the upper atmosphere on the tropic becomes clear. After the scalability problem will be resolved, we will systematically increase resolution and discussed the model convergence for both of models.

Another test case is Jablonowski & Williamson Test Case, which is a deterministic baroclinic test case. In the original paper, the equilibrium state is formulated by eta-coordinate in the vertical direction. We are now changing this condition to one by z-coordinate. T.

8.3.3. Grand challenge run by NICAM

In FY2011, we have computationally tuned NICAM with AICS Operations and Computer Technologies Division so as to efficiently conduct it on K Computer. We have also prepared to conduct a grand challenge simulation, which tremendously increases the resolution by 800m horizontal grid and 96 vertical layers. We mainly have made efforts of reduction of the memory load/store. As a result, we got 7% sustained performance in the configuration of grand challenge run.

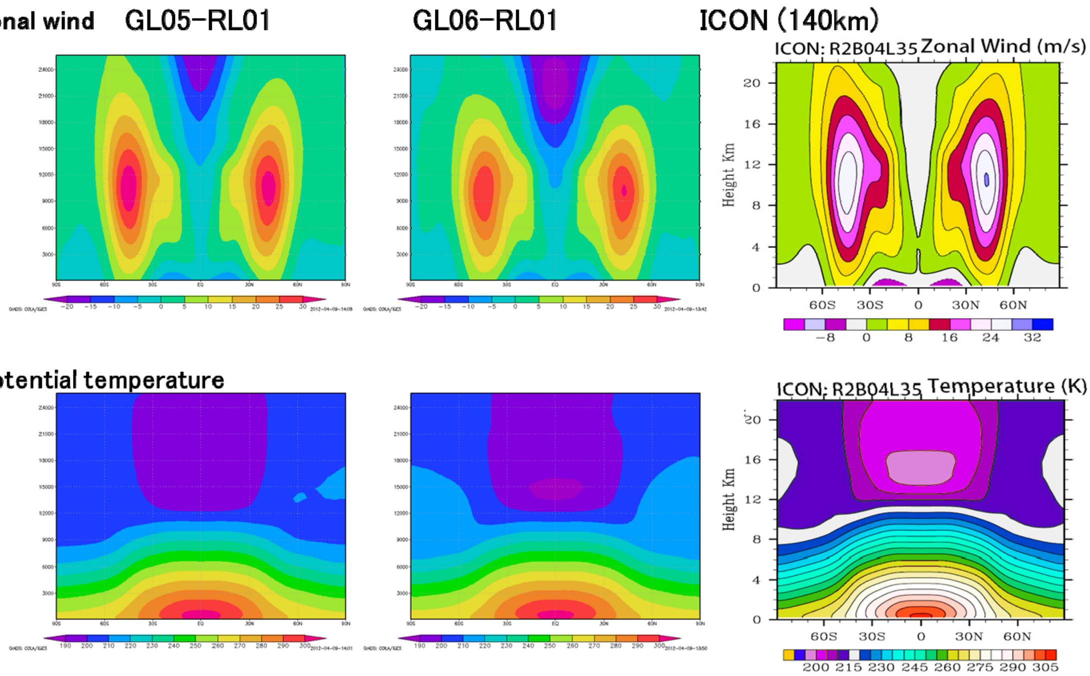

Figure 3. The inter-comparison for Held & Suarez Test Case. Climatology of zonal wind and temperature.

8.4. Schedule and Future Plan

In the next year, we will continue the feasibility study for the fast numerical library on K computer. Especially, we will give an insight into what kind of the time integration method is promising on K computer from the viewpoints of computational and physical performances. Further, we will go ahead with the construction of numerical library, considering the I/O and communication. The first version will be released by the end of FY2013.

In the ICOMEX, we also continue to do model inter-comparison, adding MPAS as soon as its code will be provided from the U.K. team. Until the end of the next fiscal year, the measures of computational and physical performance for NICAM, ICON, and MPAS will be finished and such information will be provided to other country teams (German, France, U.K., and U.S.).

We also will conduct the grand challenge run by NICAM with sub-km horizontal resolution, cooperating with the 3rd Strategic Field Project.

8.5. Publication, Presentation and Deliverables

(1) Journal Papers

1. S. Iga, H. Tomita, Y. Tsushima, M. Satoh, "Sensitivity of upper tropospheric ice clouds and their impacts on the Hadley circulation using a global cloud-system resolving model.", J. Clim., 24, 2666-2679. doi: 10.1175/2010JCLI3472.1 , 2011.

2. H. Yashiro, K. Sudo, S. Yonemura and M. Takigawa, "The impact of soil uptake on the global distribution of molecular hydrogen: chemical transport model simulation", Atmos. Chem. Phys., 11, 6701–6719, doi:10.5194/acp-11-6701-201, 2011.
3. A. T. Noda, K. Oouchi, M. Satoh, H. Tomita, "Quantitative assessment of diurnal variation of tropical convection simulated by a global nonhydrostatic model without cumulus parameterization", J. Clim., accepted, 2012.
4. M. Satoh, S. Iga, H. Tomita, Y. Tsushima, A. T. Noda, "Response of upper clouds due to global warming tested by a global atmospheric model with explicit cloud processes", J. Clim., 25, 2178-2191, 2012.
5. M. Yoshizaki, K. Yasunaga, S.-I. Iga, M. Satoh, T. Nasuno, A. T. Noda, H. Tomita , "Why do super clusters and Madden Julian Oscillation exist over the equatorial region? " , SOLA, 8, 33-36, doi:10.2151/sola.2012-009, 2012.
6. M. Satoh, K. Oouchi, T. Nasuno, H. Taniguchi, Y. Yamada, H. Tomita, C. Kodama, J. Kinter III, D. Achuthavarier, J. Manganello, B. Cash, T. Jung, T. Palmer, N. Wedi, "The Intra-Seasonal Oscillation and its control of tropical cyclones simulated by high-resolution global atmospheric models", Clim. Dyn., accepted, DOI 10.1007/s00382-011-1235-6, 2011.
7. Y. Yamada, K. Oouchi, M. Satoh, A. T. Noda and H. Tomita, "Sensitivity of tropical cyclones to large-scale environment in a global non-hydrostatic model with explicit cloud microphysics", Nova Science Publishers, Inc., (Eds. K. Oouchi and H. Fudeyasu), accepted, 2011.
8. K. Oouchi, H. Taniguchi, T. Nasuno, M. Satoh, H. Tomita, Y. Yamada, M. Ikeda, R. Shirooka, H. Yamada, K. Yoneyama, "A prototype quasi real-time intra-seasonal forecasting of tropical convection over the warm pool region: a new challenge of global cloud-system-resolving model for a field campaign", Nova Science Publishers, Inc., (Eds. K. Oouchi and H. Fudeyasu), accepted, 2011.
9. P. A. Dirmeyer, B. A. Cash, J. L. Kinter III, T. Jung, L. Marx, M. Satoh, C. Stan, H. Tomita, P. Towers, N. Wedi, D. Achuthavarier, J. M. Adams, E. L. Altshuler, B. Huang, E. K. Jin and J. Manganello, "Simulating the diurnal cycle of rainfall in global climate models: Resolution versus parameterization", Clim. Dyn., in press, DOI10.1007/s00382-011-1127-9, 2011.
10. M. Satoh, S. Iga, H. Tomita, Y. Tsushima, "Response of upper clouds due to global warming tested by a global atmospheric model with explicit cloud processes", J. Climate, accepted, 2011.
11. Y. Niwa, H. Tomita, M. Satoh, R. Imasu, "A Three-Dimensional Icosahedral Grid Advection Scheme Preserving monotonicity and Consistency with Continuity for Atmospheric Tracer Transport", J. Meteor. Soc. Japan, 89, 255-268, 2011.

(2) Conference Papers

1. H. Tomita, M. Satoh, H. Miura and Y. Niwa, "Current status of nonhydrostatic modeling at NICAM", ECMWF Workshop on Non-hydrostatic Modelling, page 171-182, ECMWF, 2011.

(3) Invited Talks

1. H. Tomita, "Research of tropical meteorology and climate using K computer", Singapore-Japan High Performance Computer Workshop, Singapore, 27-28 Feb.2012.
2. H. Tomita, "The current NICAM dynamical core and future plan for its improvement", Computing in Atmospheric Sciences 2011 (CAS2K11), Annecy, Sep. 11-14, 2011.

(4) Posters and presentations

1. H. Tomita, "Development of moist-LES model in RIKEN/AICS", The 14th international specialist meeting on the next generation models on climate change and sustainability for advanced high performance computing facilities Hawaii, 12-15 Mar., 2012.
2. H. Tomita, "Present Status of K Computer and activity toward the Exa-Scale Computing", The 14th international specialist meeting on the next generation models on climate change and sustainability for advanced high performance computing facilities Hawaii, 12-15 Mar., 2012.
3. H. Tomita, "Scale library : toward the global LES", Open Science Conference on WRCP, Denver, 24-28 Oct. 2011.
4. H. Tomita, "Recent outcomes from NICAM", 6th EU-Japan Workshop on Climate Change Research, Brussels, 10-11 Oct. 2011.
5. S. Iga, "Further simulation of aqua-planet experiment using NICAM", CFMIP/GCSS/EUCLIPSE Meeting on Cloud Processes and Climate Feedbacks, Exeter, 6-10 June, 2011.
6. S. Iga, M. Tsugawa, H. Tomita, "A generalization and combination of map projection on a sphere and its application to global grid system", Workshop on Numerical Methods for Scale Interactions 2011, Hamburg, 21-23 Sep. 2011.
7. Y. Miyamoto, and T. Takemi, "A transition mechanism for the spontaneous axisymmetric intensification of tropical cyclones", 5th Korea-Japan-China Joint Conference on Meteorology, Busan, Korea, 2011.

(5) Patents and Deliverables

- None