12. Computational Climate Science Research Team

12.1. Team members

Hirofumi Tomita (Team Leader)

Shin-ichi Iga (Research Scientist)

Yoshiyuki Kajikawa (Research Scientist)

Seiya Nishizawa (Research Scientist)

Hisashi Yashiro (Research Scientist)

Yoshiaki Miyamoto (Postdoctoral Researcher)

Tatsuya Seiki (Postdoctoral Researcher)

Tsuyoshi Yamaura (Postdoctoral Researcher)

Yousuke Sato (Postdoctoral Researcher)

Ryuji Yoshida (Research Associate)

Mamiko Hata (Technical Staff)

Hiroaki Miura (Visiting Researcher)

12.2. Research Activity

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 aim 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. we have been continuing to conduct three ongoing projects and started two projects from 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 2011 through the discussion with the Strategic 5 fields (SPIRE).

2. Grand challenge run for sub-km horizontal resolution run by global cloud-resolving model:

In order to achieve an outstanding simulation on K computer in climate field, our team are conducting the simulation with super-high resolution This work are done in cooperation with the SPIRE3.

3. Feasibility study of Exa-scale computing using the general circulation model:
   The project of G8 Research Councils Initiative "ICOMEX" has been started from 2011 autumn. Through this project, a part of our team does the feasibility study of Exa-scale computing by the global cloud resolving model and conduct the inter-comparison between the existing icosahedral models.
4. Feasibility study to the future HPCI:
   In order to clarify what can be contributed from computational science to the socio/scientific field, "the Feasibility Study to the future HPCI" funded by MEXT has started from this fiscal year. RIKEN/AICS are now leading the investigation of contribution from the application side. The executive office was established in our team. We are organizing the application community of computational sciences.
5. Disaster prevention research in establishment of COE project:
   Hyogo-Kobe COE establishment project has accepted 5 subjects in the last year. One of subjects is "the computational research of disaster prevention in the Kansai area". In this subject, one of sub-subjects is "Examination of heavy-rainfall event and construction of hazard map", which our team is responsible of.

12.3. Research Results

Construction of a new library for climate study:

We are working on research and development of a library for numerical models in fluid dynamical field especially in meteorological field. We examine feasibility of numerical scheme and methods and develop new ones which are suite on massive parallel computers especially K computer. In order to validate the schemes and test their performance in atmospheric simulations, we are developing an atmospheric large-eddy simulation model. Using this model, we performed standard benchmark test cases from ideal one to realistic one, such as the gravity current experiment (Straka et al. 1993), the squall line experiment (Redelsperger et al. 2000), the stratocumulus experiment (Stevens et al. 2005) and so on. We obtained reasonable results in comparison with results in previous studies, and then confirmed validity of schemes implemented in our model. Figure 1 is a result of gravity current experiment with 1.56125m resolution. A fractal shape structure of spiral due to Kelvin-Helmholtz instability can be seen. Realistic structure of cold pool, cumulus, and velocity is simulated in a 50m-resolution experiment on squall line (Fig. 2). Figure 3 is a result of a high-resolution stratocumulus experiment and it shows that it well simulate features of stratocumulus observed in the real atmosphere. It is expected that unknown processes, such as its transition to shallow cumulus, would be clear with such high resolution experiments. High-resolution experiment on Martian planetary boundary layer for a planetary exploration project is going on using this model with Center for Planetary Science and researchers of planetary science. Our proposal on this study was accepted for general use of K computer by HCPI (project id: hp120076). Heavy rain simulation in urban area for preventing disaster is also started with Hyogo/Kobe local government, Kyoto University, and Kobe University.

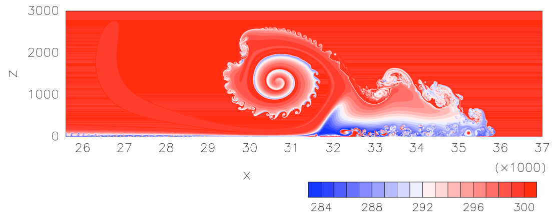

Figure 1: Potential temperature at time=570sec in a gravity current experiment with 1.5625m resolution.

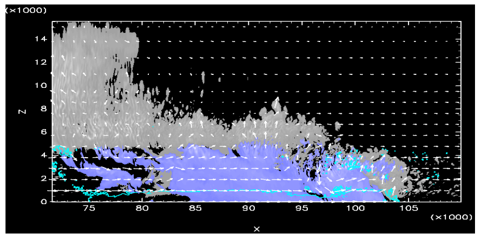

Figure 2: Horizontal-vertical cross section of rain water content (purple), othere water content (gray), temperature deviation from initial value (contour), and wind velocity (vector) in a squall

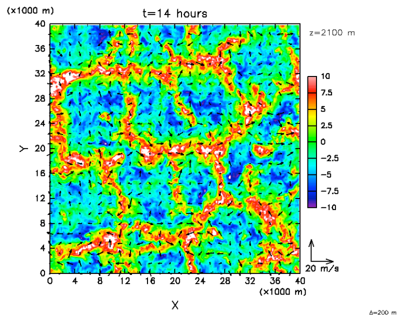

Figure. 4, Horizontal structure of convective cell at height of 2.1km in a Marian planetary boundary layer experiment. Color tone and vector show vertical velocity and horizontal velocity,

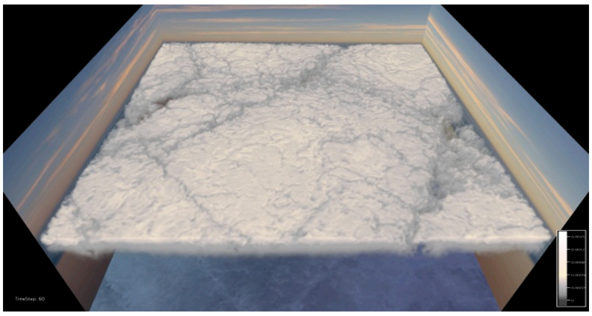

Figure 3: Could water in a stratocumulus experiment with 5m isotropic resolution.

Adding to these activities, we started collaboration with almost all major atmospheric model developing groups in Japan including Japan Meteorological Agency in developing a common basic library and environment for atmospheric models. Purpose of this activity is corporation in development of numerical code and sharing problems and knowledge for future atmospheric simulations. We are leading this activity, and held some meetings and workshop on this activity as listed below:

1. Meeting on atmospheric models, May 2012, Tokyo
2. Workshop on data analysis and numerical calculations on geophysical fluids – Current status and future plan of atmospheric/climate models in Japan -, Dec. 2012, Nagoya
3. Meeting on common basic library and environment for atmospheric models, Mar. 2013, Tokyo

Grand challenge run for sub-km horizontal resolution run by global cloud-resolving model:

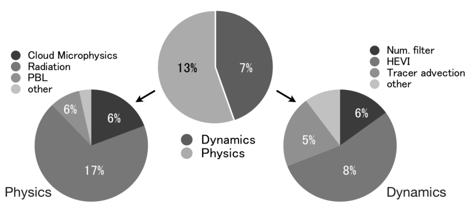

Figure 5 Detail of time and efficiency for each major component of NICAM. The size of each pie is proportional to the computational time. Each percentage represents performance efficiency.

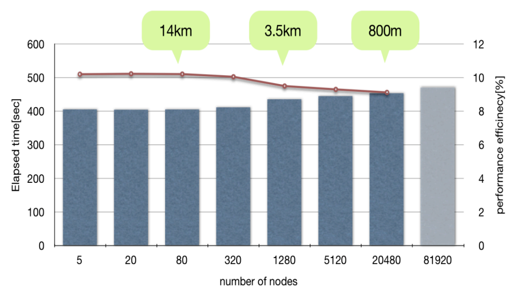

Figure 6: Weak scaling results of NICAM on the K computer. Line represents performance efficiency and Bars are elapsed time for 40 steps simulation.

Optimization of NICAM on the K computer

The optimization of NICAM on the K computer was carried out in collaboration with our team and application development team. We made cache optimization for stencil operators at first. Despite the efficiency of more than 10% was obtained in each kernel, total application performance was improved only 1%. Then we identified the part where time-consuming (large elapse time with less computation) by inserting a large number of floating-point counter and the time counter. As a result of these works, we obtain the total efficiency of about 10%. Figure 5 shows the detail of efficiency and elapse time in each major component. Figure 6 shows the result of weak scaling. It remains in the performance efficiency of ~1% reduction when we execute the model with more than 10000 nodes (80000 cores). We have good results for the almost full-node (81920 nodes) experiment. The performance of NICAM on the K computer obtained as a result of these optimizations enables the simulation such as long-term calculation, ensemble experiments, and ultra-high resolution experiments.

Grand Challenge run

We have first succeeded in conducting a Grand Challenge simulation, which includes global simulation with extremely high horizontal resolution (0.8 km) and 96 vertical levels, and simulations with varying the resolution from 30 km up to 0.8 km. We investigated the characteristic of deep moist convection in each simulation. Deep moist atmospheric convection which horizontally extends from 1 to 10 km is the element of cloudy weather disturbances such as tropical cyclones. Because of its essential importance, the convection has been modeled with special attention. However, it has been difficult to explicitly simulate the convection in global circulation models due mainly to resolution and computer performance. We used the 6 different global simulations whose horizontal resolutions is 30 km, 14 km, 7 km 3.5 km, 1.7 km and 0.8 km respectively. We defined uniform method to detect the deep convection area and convection core grid and applied to each simulation. It was revealed that the characteristics of the simulated deep moist convection (upward velocity, total number, areal ratio of convection core, and distance to the nearest convection core) were dramatically changed between the 3.5 km and 1.7 km resolutions. Thus, the present results suggest that the spatial resolution needs to be less than about 2.0 km to resolve the deep convection(Fig.7).

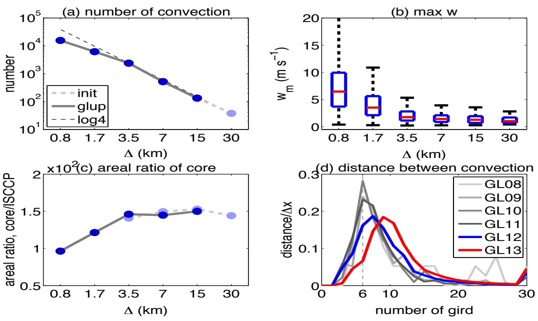

Figure 7: Resolution dependences of convection characteristics: (a) the number of convection, (b) the maximum vertical velocity, (c) the ratio of the area of convection core to that of convective grids, and (d) the grid distance to the nearest convection. The thin—dashed line in (a) indicates log x4 as a reference. GL08 denotes 30 km horizontal resolution, while GL13 indicates 0.8 km resolution.

Improvement of icosahedral grid and its family:

For stable, accurate, and cost-effective simulation in the icosahedral grid, smoothness and homogeneity are important grid properties. From this viewpoints, we investigated the grid properties and found that the stability of the spring dynamics grid decreases as the resolution increases using the standard method. To avoid this instability, the natural spring length should be shortened, while this decreases the grid homogeneity. To overcome these disadvantages, we devised a new grid-generation method that combines the spring dynamics method with a zero spring natural length and transformation by a smooth analytical function. Using this method, we found that the grid performance (homogeneity) improved at most resolutions, with the greatest increase at high resolution. We examined the grids using test case 1 of D. L. Williamson et al. (1992) and found that the proposed grid worked well in terms of accuracy and tolerability against CFL constraints.

Further, in pursuit of a computational resource cost-effective atmospheric general circulation model, a grid enhanced in the tropics was developed. The tropics-enhanced grid has about 60% of the number of grid points as the icosahedral grid. Conducting the aqua planet experiment by a quasi-uniform icosahedral grid and the grid enhanced in the tropics, we compared these results.

ICOMEX project

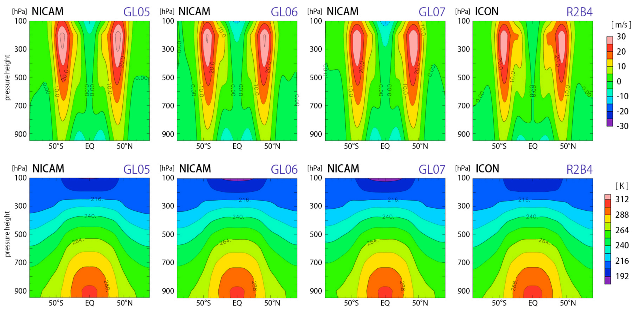

Figure 8. Zonal mean latitude-vertical profile of zonal wind and temperature for NICAM and ICON: shown values are time averaged among 1000 days after 300 days spin-up. For NICAM, horizontal resolutions for GL05, GL06, and GL07 are 240 km, 120 km, and 60 km, respectively. A horizontal resolution for ICON R2B4 is 160 km. Positive zonal wind means westerly wind.

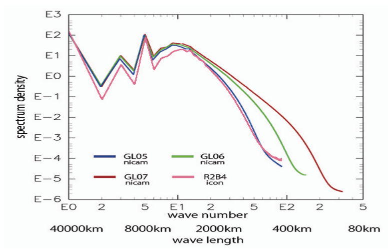

Figure 9: kinetic energy spectrum at 10 km height for NICAM and ICON: the values are calculated using u, v, and w component, and time averaged for 500 days. For NICAM, horizontal resolutions for GL05, GL06, and GL07 are 240 km, 120 km, and 60 km, respectively. A horizontal resolution for ICON R2B4 is 160 km.

The ICOsahedral-grid Models for EXascale Earth system simulations (ICOMEX) is the consortium for the climate models development toward the exascale computing. Participated are NICAM (Japan), ICON (Germany), MPAS (UK and US), and DYNAMICO (France) model teams. The Japan team works on the model inter-comparison to be synergistic among working groups. Although all the participated models use the icosahedral-grid, the discretization methods are different. We focus on both physical and computational performance.

We prepared three experiment settings. As the first step, to check physical performance, we prepared experiment setting for three test cases, which are statistical climate test, deterministic baroclinic wave test, and realistic climate test. Test production has been started for NICAM, ICON, and DYNAMICO.

Held and Suarez (1994) test case was carried out in NICAM and ICON. The profiles of temperature and zonal wind are shown in Figure 8. Temperature profiles and westerly jet were simulated reasonably both in NICAM and ICON. Figure 9 is power spectrum of kinetic energy at 10 km height. It is also reasonable that a spectrum by simulated in higher resolution has longer tail for high frequency side than spectrum tail in lower resolution.

Jablonowski and Williamson (2004, 2006) test case which is a deterministic test of baroclinic wave has been performed by using NICAM, ICON, and DYNAMICO. Wave shape and its phase are reasonable for all three models.

Feasibility study to the future HPCI:

FY2012, 5 general meetings were held and extraction of social/science subjects, which should be resolved in the next generation HPC. We also discussed about them with the other communities. The report can be found in http://hpci-aplfs.aics.riken.jp/.

Hoygo-Kobe COE establish project:

In this year, we launched the consortium of the computational research of Disaster prevention for Kansai area with Kyoto University and Kobe University, based on the Hyogo-Kobe COE. The kickoff meeting was held in AICS in January 2013.

12.4. Schedule and Future Plan

In the next year, we will continue to construct the numerical library for K computer and release the 1st version of library until the end of FY2013. At the same time , we will give an insight into what kind of the time integration method is promising on K computer and future HPC from the viewpoints of computational and physical performances. Through this project, we will organize and lead the meteorological numerical community for common library towards the post-Peta scale computing.

Grand challenge run by NICAM will be also continued in cooperation with 3rd Strategic Field Project. The statistical properties of deep convection and convergence of grid refinement will be investigated and clarified in detail.

In the ICOMEX project, we also continue to do model inter-comparison. So far, all participated model are ready to compare each other. Focusing on the physical performance, four models are inter-compared through such as aqua planet experiment.

On the Feasibility study, the science roadmap will be further brushed up with inside/outside researchers. The office of this project in our team will continue to organize the meeting and enhance the discussion. The estimation of the systems, which is proposed by 3 system-design teams will be a mission of this project. This will be performed with 3 system-design teams.

On the COE establishment project, we have a plan to use the SCALE library. In the next year, we add several components such as city-model and start to research the mechanism of heavy-rainfall in Kansai-area with collaborated organization.

12.5. Publication, Presentation and Deliverables

(1) Journal Papers

1. Oouchi, K., H. Taniguchi, T. Nasuno, M. Satoh, H. Tomita, Y. Yamada, M. Ikeda, R. Shirooka, H. Yamada, K. Yoneyama, 2012: 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, pp.233-248.
2. Yoshizaki, M., Yasunaga, K., Iga, S.-I., Satoh, M., Nasuno, T., Noda, A. T., Tomita, H., 2012: Why do super clusters and Madden Julian Oscillation exist over the equatorial region? SOLA, 8, 33-36, doi:10.2151/sola.2012-009.
3. Noda, A. T., Oouchi, K., Satoh, M., Tomita, H., 2012: Quantitative assessment of diurnal variation of tropical convection simulated by a global nonhydrostatic model without cumulus parameterization. J. Clim., 25, 5119-5134.
4. Satoh, M., Iga, S., Tomita, H., Tsushima, Y., Noda, A.T., 2012: Response of upper clouds due to global warming tested by a global atmospheric model with explicit cloud processes. J. Clim., 25, 2178-2191.
5. Dirmeyer, P. A., Cash, B. A.,Kinter III, J. L., Jung, T., Marx, L., Satoh, M., Stan, C., Tomita, H., Towers, P., Wedi, N., Achuthavarier, D., Adams, J. M., Altshuler, E. L., Huang, B., Jin, E. K., and Manganello, J., 2012: Simulating the diurnal cycle of rainfall in global climate models: Resolution versus parameterization. Clim. Dyn., 39, 399-418, DOI10.1007/s00382-011-1127-9.
6. Miyamoto, Y. and T. Takemi, 2013: A transition mechanism for spontaneous intensification of tropical cyclones. J. Atmos. Sci., 70, 112-129.
7. Fudeyasu, H. and Y. Miyamoto, 2013: Intensification phase and steady state, *Meteorological Research Note*, 226.
8. Yoshizaki, M., S. Iga, and M. Satoh 2012:Eastward-propagating property of large-scale precipitation systems simulated in the coarse- resolution NICAM and an explanation of its formation.: Scientific Online Letters on the Atmosphere , 8, pp.21-24,
9. Yoshida R., and H. Ishikawa, 2013: Environmental factors contributing to tropical cyclone genesis over the western North Pacific. Mon. Wea. Rev., 141, 451–467.
10. Yamaura, T. and T. Tomita, 2012: Covariability between the Baiu precipitation and tropical cyclone activity through large-scale atmospheric circulation. J. Meteor. Soc. Japan, 90, 449-465.

(2) Conference Papers

-None

(3) Invited Talks

1. Tomita, H.: SCALE toward the library of meteorological applications suitable to the future super Toward Global LES, 5th International Workshop on Cloud-Resolving Global Modelling, 13-15th June 2012 (invited)
2. Tomita, H., Japanese Post-Peta Planning and Feasibility Research, Application, 18th International Exa-scale Software Project, 11-13 April 2012 (invited)
3. Tomita, H. Research of tropical meteorology and climate using K computer, Singapore-Japan High Performance Computer Workshop, Singapore, 27-28 Feb.2012 (invited)
4. Yashiro, H., NICAM.12: Recent Performance on the K Computer and Further Development toward Post Peta-scale Computing (Invited), 2012 KIAPS International Symposium, Seoul, Korea, Nov. 2012.

(4) Posters and presentations

International and Domestic conference/symposium/workshop

1. Tomita, H., S. Nishizawa, H. Yashiro SCALE-LES: Strategic development toward the future global LES, 1st International Conference on Frontiers in Computational Physics: Modeling the Earth System, Boulder, CO, USA 16 - 20 December 2012
2. Tomita, H: SCALE-LES: Strategic development of large eddy simulation suitable to the future HPC, Solution of Partial Differential Equations on the Sphere (PDEs on the sphere), 24-28 September, 2012, Cambridge
3. Tomita, H. : 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
4. Tomita, H. : 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
5. Sato, Y., H.Yashiro, S. Nishizawa, Y.Miyamoto, H. Tomita, and Team-SCALE : Development of SCALE-LES3 model and numerical simulations of shallow clouds by the model, *Second International Workshop on Nonhydrostatic Numerical Models*, Sendai, Japan, November, 2012
6. Sato, Y., H. Yashiro, S. Nishizawa, Y. Miyamoto, H. Tomita: Development of SCALE-LES3 model and numerical simulation of shallow clouds by the model, *1st International conference on Frontires in computational physics: Modeling the earth system*, O15, Boulder, CO, USA, December, 2012

7. Sato, Y., H. Yashiro, S. Nishizawa, Y. Miyamoto, Team-SCALE, and H. Tomita: Numerical simulations of shallow clouds by using SCALE-LES, Autumn Meeting, Meteorological Society of Japan, Sapporo, 3-5, Oct., 2012.
8. Miyamoto, Y., H. Yashiro, S. Nishizawa, Y. Sato, H. Tomita and Team SCALE, 2012: Impacts of numerical grid on atmospheric boundary-layer turbulence in large eddy simulations using a fully compressible model., *1st International Conference on Frontiers in Computational Physics,* Boulder, Colorado, U.S.A..
9. Miyamoto, Y. and T. Takemi, 2012: A transition mechanism for the spontaneous axisymmetric intensification of tropical cyclones.. *2012 AGU fall meeting, San Francisco*, U.S.A..
10. Miyamoto, Y., H. Yashiro, S. Nishizawa, Y. Sato, H. Tomita and Team SCALE, 2012 : Impacts of numerical grid on atmospheric boundary-layer turbulence in large eddy simulations using a fully compressible model. *2nd International workshop on Non-hydrostatic modeling*, Sendai, Japan.
11. Miyamoto, Y. and T. Takemi, 2012: An effective radius of the sea surface enthalpy flux for the maintenance of a tropical cyclone. *18th Conference on Air-Sea Interaction*, Boston, U.S.A.
12. Miyamoto, Y. and T. Takemi, 2012: A transition mechanism for the spontaneous axisymmetric intensification of tropical cyclones. *30th Conference on Hurricanes and Tropical Meteorology*, Ponte Vedra Beach, Florida, U.S.A..
13. Miyamoto, Y. and T. Takemi, 2012: An effective radius of the sea surface enthalpy flux for the maintenance of a tropical cyclone. *Ocean Sciences Meeting 2012*, Salt Lake City Utah, U.S.A.
14. Miyamoto, Y., H. Yashiro, S. Nishizawa, Y. Sato, H. Tomita and Team SCALE, 2012 : The effects of grid shape on boundary-layer turbulence above a heated surface. Meteorological Society of Japan, Sapporo, Oct. 4th, 2012.
15. Miyamoto, Y., 2012 :Maximum potential intensity theory of tropical cyclones including the ocean cooling process: A discussion on the nondimensional parameter. Meteorological Society of Japan, Sapporo, Oct. 4th, 2012.
16. Miyamoto, Y., T. Takemi, 2012 : The trigger of spontaneous axisymmetric intensification of tropical cyclones Meteorological Society of Japan, Tokyo, May 20th, 2012.
17. Iga, S., H. Tomita, M.Tsugawa 2012, A generalization and combination of map projection on a sphere and its application to global grid system. The 14th international specialist meeting on the next generation models of climate change and sustainability for advanced high performance computing facilities. (2012.03.12-15, Maui, Hawaii,)
18. Yoshida R., 2012: A development process of the tropical disturbance observed in PALAU2010 for understanding tropical cyclogenesis. *30th Conference on Hurricanes and Tropical Meteorology*, Ponte Vedra Beach, Florida, U.S.A.
19. Yoshida R., and H. Tomita, 2012: G8 ICOMEX: Introduction & preliminary result. 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

20. Yoshida R., and H. Tomita, 2012: NICAM presentation and evolution, G8 ECS workshop, 6-7 March, 2012 at Aachen, Germany
21. Yoshida R., and H. Tomita, 2012: G8 call: ICOMEX project - the introduction, G8 ECS workshop, 6-7 March, 2012 at Aachen, Germany
22. Yoshida R., and H. Tomita, 2012: An Inter-Comparison of Icosahedral Climate Models on the G8 Call: ICOMEX Project. Solution of Partial Differential Equations on the Sphere (PDEs on the sphere), 24-28 September, 2012, Cambridge
23. Yoshida R., H. Tomita, M. Satoh: An inter-comparison of icosahedral grid models - G8 Call:ICOMEX Project, 2012 Autumn Meeting, Meteorological Society of Japan, Sapporo, 3-5, Oct., 2012.
24. Seiki, T., M. Satoh, T. Nakajima, and H. Tomita, 2012: Aerosol effects of the condensation process on a tropical squall line simulation. 16th International Conference on Clouds and. Precipitation, Leipzig, Germany
25. Seiki, T., D. Goto, K. Suzuki, M. Satoh, and H. Tomita, 2012: Modeling of wet deposition process coupled with a double moment bulk cloud microphysics scheme, 11th AEROCOM Workshop, Seattle, USA
26. Yamaura, T. and T. Tomita, 2012: Subseasonal change in interannual variations of the Baiu precipitation. AGU Fall Meeting 2012, 3-7 December, San Francisco, CA, USA.
27. Yamaura, T. and T. Tomita, 2012: Covariability between the Baiu precipitation and tropical cyclone activity through large-scale atmoshperic circulation. AOGS-AGU 2012, AS01-A007, 13-17 August, Singapore.
28. Yamaura, T., T. Tomita, 2012: Subseasonal change in the interannual variability of the Baiu precipitation. Meteorological Society of Japan 2012 Fall meeting, P180, 3-5 October 2012, Hokkaido University, Hokkaido.
29. Yamaura, T., T. Tomita, 2012: Covariability between the Baiu precipitation and tropical cyclone activity through large-scale atmospheric circulation. Meteorological Society of Japan 2012 Spring meeting, B166, 26-29 May 2012, Tsukuba International Congress Center, Tsukuba.
30. Yamaura, T., T. Tomita, 2012: Covariability between the Baiu precipitation and tropical cyclone activity through large-scale atmospheric circulation. Japan Geoscience Uniton 2012 Annual meeting, AAS23-P11, 20-25 May 2012, Makuhari Messe International Convention Complex, Chiba.
31. Kajikawa, Y., Wang B. and H. Murakami, 2012: South China Sea summer monsoon onset simulated by the high-resolution MRI-AGCM, AGU Fall Meeting 2012, 3-7 December, San Francisco, CA, USA.

32. Kajikawa, Y., Wang B. and H. Murakami, 2012: South China Sea summer monsoon onset simulated by the high-resolution MRI-AGCM, Meteorological Society of Japan 2012 Fall meeting, P180, 3-5 October 2012, Hokkaido University, Hokkaido.
33. Tomita, H., Introduction of Japanese activities toward the Exa-scale computing, The workshop for next-generation of climate models and knowledge discoveries through the extreme high performance simulations and big data, Berkeley, CA, USA, 2012
34. Nishizawa, S., Yashiro,H., Sato,Y.,Miyamoto,Y., Tomita,H. and Team SCALE, Research and Development of Common Basic Library and Environment for Weather and Climate Prediction Models, The workshop for next-generation of climate models and knowledge discoveries through the extreme high performance simulations and big data, Berkeley, CA, USA, 2012
35. Nishizawa. S., H. Yashiro, Y. Miyamoto, M. Odaka, Y. Takahashi, Y.-Y. Hayashi, H. Tomita, S. Takehiro, M. Ishiwatari, K. Nakajima, Y. Sato, K. Sugiyama, Team SCALE, and GFD Dennou Club: A large-eddy simulation experiment on turbulence in Martian planetary boundary layer, 2012 Autumn Meeting of Meteorological Society of Japan, Sapporo, Japan, October, 2012
36. Nishizawa. S., H. Yashiro, Y. Miyamoto, M. Odaka, Y. Takahashi, Y.-Y. Hayashi, H. Tomita, S. Takehiro, M. Ishiwatari, K. Nakajima, Y. Sato, K. Sugiyama, Team SCALE, and GFD Dennou Club: A large-eddy simulation experiment on turbulence in Martian planetary boundary layer, 2012 Annual Meeting of the Japanese Society for Planetary Sciences, Kobe, Japan, October, 2012
37. Yashiro,H., Tomita,H. and Satoh,M., NICAM simulations on the K computer: recent performance and activities toward to the exascale computing, The workshop for next-generation of climate models and knowledge discoveries through the extreme high performance simulations and big data, Berkeley, CA, USA, 2012
38. Sawada,M., Miyagawa,T., Nakano,M., Yamaura, T., Noda,A.T., Kajikawa,Y., Yamada,Y., and Satoh,M., Study of extended-range predictability using global cloud system resolving model NICAM, The workshop for next-generation of climate models and knowledge discoveries through the extreme high performance simulations and big data, Berkeley, CA, USA, 2012

(5) Patents and Deliverables

-None