

台風全域ラージ・エディ・シミュレーション

Large Eddy Simulation of Entire Tropical Cyclone

*伊藤 純至^{1,3}、大泉 伝²、新野 宏³

*Junshi Ito^{1,3}, Tsutao OIZUMI², Hiroshi Niino³

1. 気象研究所、2. 海洋研究開発機構、3. 東京大学

1. Meteorological Research Institute, Japan Meteorological Agency, 2. JAMSTEC, 3. The University of Tokyo

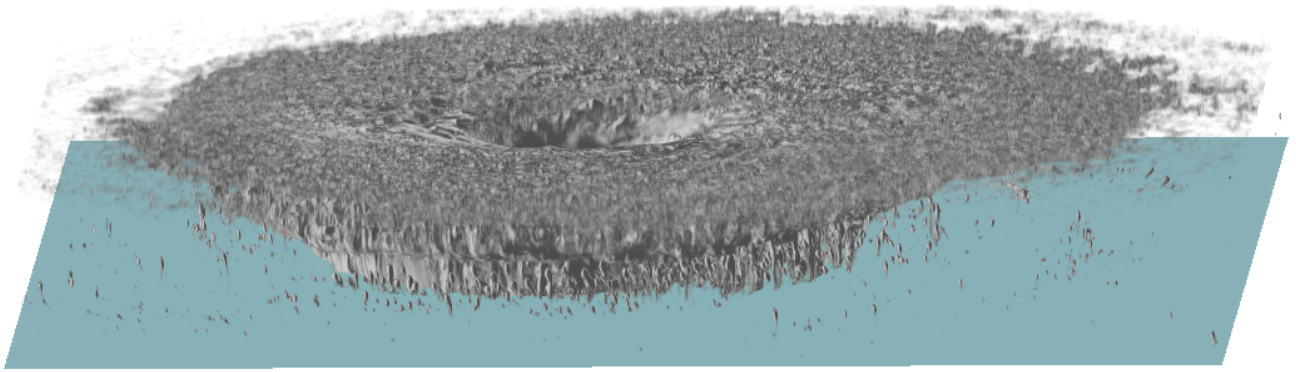
Most numerical models of a tropical cyclone do not have a resolution to explicitly simulate turbulent eddies, but their effects are parameterized. Such parameterizations must introduce significant uncertainties. Large Eddy Simulation (LES) which resolve the eddies can mitigate the uncertainties, while it requires more computational resources.

Taking advantage of the huge computational power of a massive parallel supercomputer (K-supercomputer, AICS, RIKEN), LES of entire tropical cyclones is realized. A regional numerical weather prediction model used in this study is Japan Meteorological Agency's Non-Hydrostatic Model (JMA-NHM). The computational domain covers 2000 km by 2000 km in the horizontal and 23 km in the vertical directions, and horizontal boundary conditions are doubly cyclic. The grid number is 20000 by 20000 in the horizontal directions, and 60 in the vertical direction where grid spacing increases with increasing height. Before starting the LES, a preliminary run with JMA-NHM with $dx=2\text{km}$ is made. In this preliminary run, a tropical cyclone develops from a weak initial vortex to a mature stage after 120 hours integration. The grid point values of this mature stage are interpolated to prepare the initial condition for the LES. The time integration of the LES is then performed for 10 hours.

Figure exhibits the cloud amount (mixing ratio of hydrometers) of a reproduced tropical cyclone in the LES. The wall cloud around the eye consist of a number of cumulus clouds. Although the fine scale structures are resolved in the LES, the maximum of the near-surface wind changes little from that simulated based on coarse-resolution runs. The boundary layer height is smaller in the LES, and this may shrink the radius of the maximum wind

We explore especially near-surface coherent structures in the TC boundary layer. Three kinds of coherent structures appeared inside the boundary layer: Type-A roll, which is caused by an inflection-point instability of the radial flow and prevails outside the radius of maximum wind. The second is a Type-B roll that also appears to be caused by an inflection-point instability but of both radial and tangential winds. Its roll axis is almost orthogonal to the Type-A roll. The third is a Type-C roll, which occurs inside the radius of maximum wind and only near the surface. It transports horizontal momentum flux in an up-gradient sense and causes the largest gusts.

キーワード：台風、ラージ・エディ・シミュレーション、スーパーコンピュータ、乱流、領域気象モデル
Keywords: Tropical Cyclone, Large Eddy Simulation, Supercomputer, Turbulence, Regional Weather Prediction Model



Effects of cloud condensate vertical alignment on radiative transfer calculations in deep convective regions

*Xiacong Wang¹

1. Institute of Atmospheric Physics

Effects of cloud condensate vertical alignment on radiative transfer process were investigated using cloud resolving model explicit simulations, which provide a surrogate for subgrid cloud geometry. Diagnostic results showed that the decorrelation length L_{cw} varies in the vertical dimension, with larger L_{cw} occurring in convective clouds and smaller L_{cw} in cirrus clouds. A new parameterization of L_{cw} is proposed that takes into account such varying features and gives rise to improvements in simulations of cloud radiative forcing (CRF) and radiative heating, i.e., the peak of bias is respectively reduced by 8 W m^{-2} for SWCF and 2 W m^{-2} for LWCF in comparison with $L_{cw} = 1 \text{ km}$.

The role of L_{cw} in modulating CRFs is twofold. On the one hand, larger L_{cw} tends to increase the standard deviation of optical depth $\sigma \tau$, as dense and tenuous parts of the clouds would be increasingly aligned in the vertical dimension, thereby broadening the probability distribution. On the other hand, larger $\sigma \tau$ causes a decrease in the solar albedo and thermal emissivity, as implied in their convex functions on τ . As a result, increasing (decreasing) L_{cw} leads to decreased (increased) CRFs, as revealed by comparisons among $L_{cw} = 0$, $L_{cw} = 1 \text{ km}$ and $L_{cw} = \infty$. It also affects the vertical structure of radiative flux and thus influences the radiative heating. A better representation of $\sigma \tau$ in the vertical dimension yields an improved simulation of radiative heating. Although the importance of vertical alignment of cloud condensate is found to be less than that of cloud cover in regards to their impacts on CRFs, it still has enough of an effect on modulating the cloud radiative transfer process.

Keywords: horizontal inhomogeneity, vertical alignment, cloud resolving model

The Impact of Dimensionality on Barotropic Processes during KWAJEX

*Xiaofan Li¹

1. Zhejiang University

In this study, the two-dimensional (2D) and three-dimensional (3D) cloud-resolving model simulations of the Tropical Rainfall Measuring Mission (TRMM) Kwajalein Experiment (KWAJEX) are compared to study the impact of dimensionality on barotropic processes during tropical convective development. Barotropic conversion of perturbation kinetic energy is associated with vertical transport of horizontal momentum under vertical shear of background horizontal winds. The similarities in both model simulations show that (1) vertical wind shear is a necessary condition for barotropic conversion, but it does not control the barotropic conversion; (2) the evolution of barotropic conversion is related to that of the vertical transport of horizontal momentum; (3) the tendency of vertical transport of horizontal momentum is mainly determined by the horizontal transport of cloud hydrometeors. The differences between the 2D and 3D model simulations reveal that (1) the barotropic conversion has shorter time scales and larger amplitudes in the 2D model simulation than in the 3D model simulation; (2) kinetic energy is generally converted from the mean circulations to perturbation circulations in the 3D model simulation. In contrast, more kinetic energy is transferred from perturbation circulations to the mean circulations in the 2D model simulation; (3) there is no statistical relation in barotropic conversion between the 2D and 3D model simulations.. The same large-scale vertical velocity may account for the similarities whereas the inclusion of meridional winds in the 3D model simulation may be responsible for the differences in barotropic conversion between the 2D and 3D model simulations.

Keywords: Cloud-resolving model, barotropic conversion, vertical wind shear

A numerical study of ice nucleation process and crystal habit for Arctic mixed-phase clouds

*Tempei Hashino¹, Gijs de Boer², Hajime Okamoto¹

1. Kyushu University, 2. Univeristy of Colorado at Boulder

In this presentation, the ice nucleation processes and ice crystal habits are investigated numerically for Arctic mixed-phase stratus. Arctic region is well known for its high sensitivity to climate change and the liquid-containing clouds play an important role in the surface energy budgets as well as at TOA. In our previous studies (de Boer et al. 2010, 2013), it was hypothesized that the immersion freezing process is the key self regulating process where the large droplets freeze quickly and fall out of the super-cooled layer. Our 2D LES experiments highlighted the importance of insoluble characteristics of aerosol particles instead of soluble fraction. However, we did not take into account the condensation freezing (or deliquescence freezing) mode. This time we use a classical nucleation theory approach to deal with the ice nucleation modes more rigorously and implement 3D LES experiments.

The dynamic model is UW-NMS (Tripoli 1992) and the cloud microphysical scheme is AMPS (Hashino and Tripoli 2007, 2008, 2011 ab). The ice part of AMPS (SHIPS) is particularly unique in that it predicts ice crystal habits explicitly, thus it is suitable to study ice nucleation process for the mixed-phased clouds. The case studies were chosen from SHEBA (Surface Heat Budget of the Arctic Ocean) and ISDAC (Indirect and Semi-Direct Aerosol Campaign) field campaigns. We will discuss the dominant mode of ice nucleation and resulting habits with parcel model settings and LES experiments. Furthermore, to better understand the applicability of the classical nucleation theory approach to cloud-resolving simulations, we will simulate the same cases with larger spatial resolution.

Keywords: Arctic clouds, Ice nucleation, crystal habit

CALIPSOとCloudSat衛星データを複合利用した雲氷シミュレーションの評価

Evaluation of simulated ice clouds using joint CALIPSO and CloudSat satellite observations

*清木 達也¹、小玉 知央¹、佐藤 正樹²、端野 典平³、萩原 雄一郎⁴、岡本 創³

*Tatsuya Seiki¹, Chihiro Kodama¹, Masaki Satoh², Tempei Hashino³, Yuichiro Hagihara⁴, Hajime Okamoto³

1. 海洋研究開発機構、2. 東京大学、3. 九州大学、4. 宇宙航空研究開発機構

1. Japan Agency for Marine-Earth Science and Technology, 2. The University of Tokyo, 3. Kyushu University, 4. Japan Aerospace Exploration Agency

本研究ではCloudSatとCALIPSO衛星を複合的に利用することで雲氷シミュレーションを評価する手法を新しく開発した。この手法は雲頂からの雲光学的厚さを鉛直座標とし、様々な雲微物理量の鉛直分布を評価する手法である。

キーワード：雲微物理、氷雲、気候モデル

Keywords: Cloud Microphysics, Ice Clouds, Climate Modeling

Suggestions from a global cloud system resolving simulation to global climate model -Transportation of black carbon aerosol to the Arctic-

*佐藤 陽祐¹、三浦 裕亮²、八代 尚¹、五藤 大輔³、竹村 俊彦⁴、道端 拓朗⁴、鈴木 健太郎⁵、中島 映至⁶
*Yousuke Sato¹, Hiroaki Miura², Hisashi Yashiro¹, Daisuke Goto³, Toshihiko Takemura⁴, Takuro Michibata⁴, Kentaroh Suzuki⁵, Teruyuki Nakajima⁶

1. 理化学研究所計算科学研究機構、2. 東京大学大学院地球惑星科学専攻、3. 国立環境研究所、4. 九州大学応用力学研究所、5. 東京大学大気海洋研究所、6. 宇宙航空研究開発機構地球観測研究センター

1. RIKEN Advanced Institute for Computational Science, 2. Department of Earth and Planetary Science, The University of Tokyo, 3. National Institute for Environmental Studies, 4. Research Institute for Applied Mechanics, Kyushu University, 5. Atmosphere Ocean Research Institute, The University of Tokyo, 6. Earth Observation Research Center, Japan Aerospace Exploration Agency

In this study, we investigated effects of horizontal grid resolution on the transportation of black carbon aerosol (BCA) to the Arctic region. BCA in the Arctic has unique and large impact on the climate system through changing the albedo of snow-covered surface as well as absorbing and scattering sunlight. Despite its profound impact, most of the current generation general circulation models (GCM) underestimate BCA in the Arctic. To clarify the reason of the underestimation, the global aerosol transport simulation with kilometer order resolution (3.5km) was conducted. We also conducted sensitivity experiments with coarsening horizontal grid resolution from 3.5 km to 56 km to investigate the impacts of horizontal grid resolution. Our results indicated that BCA mass concentration in the Arctic increased with fining grid resolution, and the BCA mass concentration in the Arctic simulated with the 3.5-km grid resolution was 4.2 times larger than that simulated with a coarse (56-km) grid resolution. The underestimation of BCA was reduced by fining the grid resolution. Results of this study propose that global simulations using kilometre-order or finer horizontal resolution can lead to more accurate estimations of the distribution of BCA in the Arctic and reduce uncertainties regarding the effects of aerosols on global climate. As well as the BCA, we will introduce the several results of global cloud system resolving simulation coupled with aerosol transport model.

キーワード：黒色炭素、雲解像モデル、エアロゾル輸送モデル

Keywords: Black carbon aerosol, Cloud system resolving model, Aerosol transport model

Using Global Mesoscale Model Results to inform GEOS GCM Moist Process Parameterizations

*Andrea Molod¹, Donifan Barahona¹, Nathan Arnold¹

1. NASA Goddard Space Flight Center

The GEOS Atmospheric General Circulation Model (AGCM) is currently in use in the NASA Global Modeling and Assimilation Office (GMAO) at a wide range of resolutions for a variety of applications including atmospheric analyses and forecasts, coupled atmosphere-ocean simulations and global mesoscale simulations. A global mesoscale simulation at approximately 7-km horizontal resolution was used to examine the subgrid-scale variability of several fields within several coarser-resolution grid sizes. These subgrid scale variances are relevant for informing the parameterization of moist processes in the GEOS GCM, and are the total water, relevant for the cloud macrophysics, the vertical velocity, relevant for the cloud microphysics related to cirrus formation, and the near-surface moist static energy, relevant for the cumulus parameterization. The analysis of the global mesoscale model output also allowed a proper implementation of resolution dependant behavior in the parameterizations. Modification of the parameterizations using the subgrid scale information were implemented in the GCM and the impact on the AGCM simulations will be presented here. The statistics of total water and vertical velocity had a positive impact on the simulations, and the moist static energy impact is still under development.

Keywords: GCM, Moist Processes, Parameterization

RCEMIP: 放射対流平衡モデル比較実験プロジェクト

RCEMIP: Radiative Convective Equilibrium Model Inter-comparison Project

*佐藤 正樹¹、大野 知紀¹、Allison Wing²、Sandrine Bony³、Bjorn Stevens⁴、Kevin Reed⁵

*Masaki Satoh¹, Tomoki Ohno¹, Allison Wing², Sandrine Bony³, Bjorn Stevens⁴, Kevin Reed⁵

1. 東京大学大気海洋研究所、2. Department of Earth, Ocean, and Atmospheric Science, Florida State University, USA、3. Laboratoire de Météorologie Dynamique, IPSL, CNRS, Paris, France、4. Max-Planck Institute for Meteorology, Hamburg, Germany、5. School of Marine and Atmospheric Science, Stony Brook University, NY, USA
1. Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan, 2. Department of Earth, Ocean, and Atmospheric Science, Florida State University, USA, 3. Laboratoire de Météorologie Dynamique, IPSL, CNRS, Paris, France, 4. Max-Planck Institute for Meteorology, Hamburg, Germany, 5. School of Marine and Atmospheric Science, Stony Brook University, NY, USA

Radiative Convective Equilibrium Model Inter-comparison Project (RCEMIP) is proposed.

Radiative-convective equilibrium (RCE) is referred to as atmospheric quasi statistical balance between convection and radiation processes (Manabe and Strickler 1964). Historically, RCE has been argued mainly with one-dimensional models, but in recent years more computationally intensive numerical calculations of RCE have been conducted with three-dimensional numerical models with explicitly resolved convection and domain lengths of 100-1000 km. A simple horizontally uniform boundary condition is prescribed with a constant sea surface temperature (SST) or a slab ocean model with uniform solar insolation. Since clouds are a most ambiguous part of climate models, the simple framework of RCE is suitable for understanding how clouds are simulated in numerical models. RCE is also useful to clarify the sensitivities of clouds to the details of cloud schemes implemented in numerical models (e.g., Satoh and Matsuda 2008). A number of RCE numerical studies have been conducted until recently with their own various configurations. One category is RCE on the sphere either with or without a cumulus parameterization scheme (e.g., Popke et al., 2013; Arnold and Randall, 2015; Reed et al., 2015; Bony et al., 2016; Satoh et al., 2016; Ohno and Satoh, 2016). The other category is RCE with regional models in an arbitrary domain size, primarily with explicitly resolved convection (e.g., Wing and Cronin 2016; Silvers et al. 2016). In order to systematically understand differences or similarities of various model results, a more coordinated framework for RCE numerical studies is demanded as “RCEMIP”. Possible choices for experimental settings of RCE are listed as follows:

Geometry: sphere / plane (square or channel)

Domain size: Earth radius R / length=40,000 km \times factor (e.g., 0.1–1.0)

Horizontal resolution: $\Delta x = 1-10$ km for explicit convection, or coarser resolution (1–2 degree) with a cumulus parameterization

Boundary condition: fixed SST (e.g., 296, 300, 304K) or a slab ocean

CO₂: a current value or increased (e.g., 4 \times CO₂)

Physics dependency: cloud microphysics, turbulence, radiation,; switch on/off of cumulus parameterization

Interactive radiation or non-interactive, with/without clouds

With or without diurnal cycle

Without rotation, or with rotation

Among a lot of varieties listed above, we will discuss the experimental design of RCEMIP, scientific targets, and how to proceed. One strength of RCEMIP is the numerous scientific questions that could be explored, such as better understanding of uncertainties of climate sensitivities and changes in clouds and

circulations, or convective aggregation, associated with global warming.

References:

- Arnold, N. P., and D. A. Randall, 2015: Global-scale convective aggregation: Implications for the Madden-Julian Oscillation. *J. Adv. Model. Earth Syst.*, **7**, 1499-1518.
- Bony, S. et al., 2016: Thermodynamic control of anvil cloud amount. *PNAS*, **113**, 8927-8932.
- Manabe, S., and R. F. Strickler, 1964: Thermal equilibrium of the atmosphere with a convective adjustment. *J. Atmos. Sci.*, **21**, 361-385.
- Ohno, T., and M. Satoh, 2016: Sensitivity studies of cloud responses on SSTs in RCE experiments using a high-resolution global nonhydrostatic model. The 4th International Workshop on Nonhydrostatic Models., Hakone, Japan. Nov. 30 - Dec. 2, 2016.
- Popke, D. et al., 2013: Climate and climate change in a radiative-convective equilibrium version of ECHAM6. *J. Adv. Model. Earth Syst.*, **5**, 1-14.
- Reed, K. et al., 2015: Global Radiative-Convective Equilibrium in the Community Atmosphere Model, Version 5. *J. Atmos. Sci.*, **72**, 2183-2197.
- Satoh, M., and Y. Matsuda, 2009: Statistics on high-cloud areas and their sensitivities to cloud microphysics using single-cloud experiments. *J. Atmos. Sci.*, **66**, 2659-2677.
- Satoh, M. et al., 2016: Structure of tropical convective systems in aqua-planet experiments: Radiative-convective equilibrium versus the Earth-like experiment. *SOLA*, **12**, 220-224.
- Silvers, L. G. et al., 2016: Radiative convective equilibrium as a framework for studying the interaction between convection and its large-scale environment. *J. Adv. Model. Earth Syst.*, **8**, 1330-1344.
- Wing, A. A., and T. W. Cronin., 2016: Self-aggregation of convection in long channel geometry. *Q. J. Roy. Meteor. Soc.*, **142**, 1-15.

キーワード：放射対流平衡、雲解像モデル、大気大循環モデル、モデル比較実験、RCEMIP

Keywords: radiative convective equilibrium, cloud resolving model, general circulation model, model intercomparison project, RCEMIP

The Environment of Aggregated Deep Convection

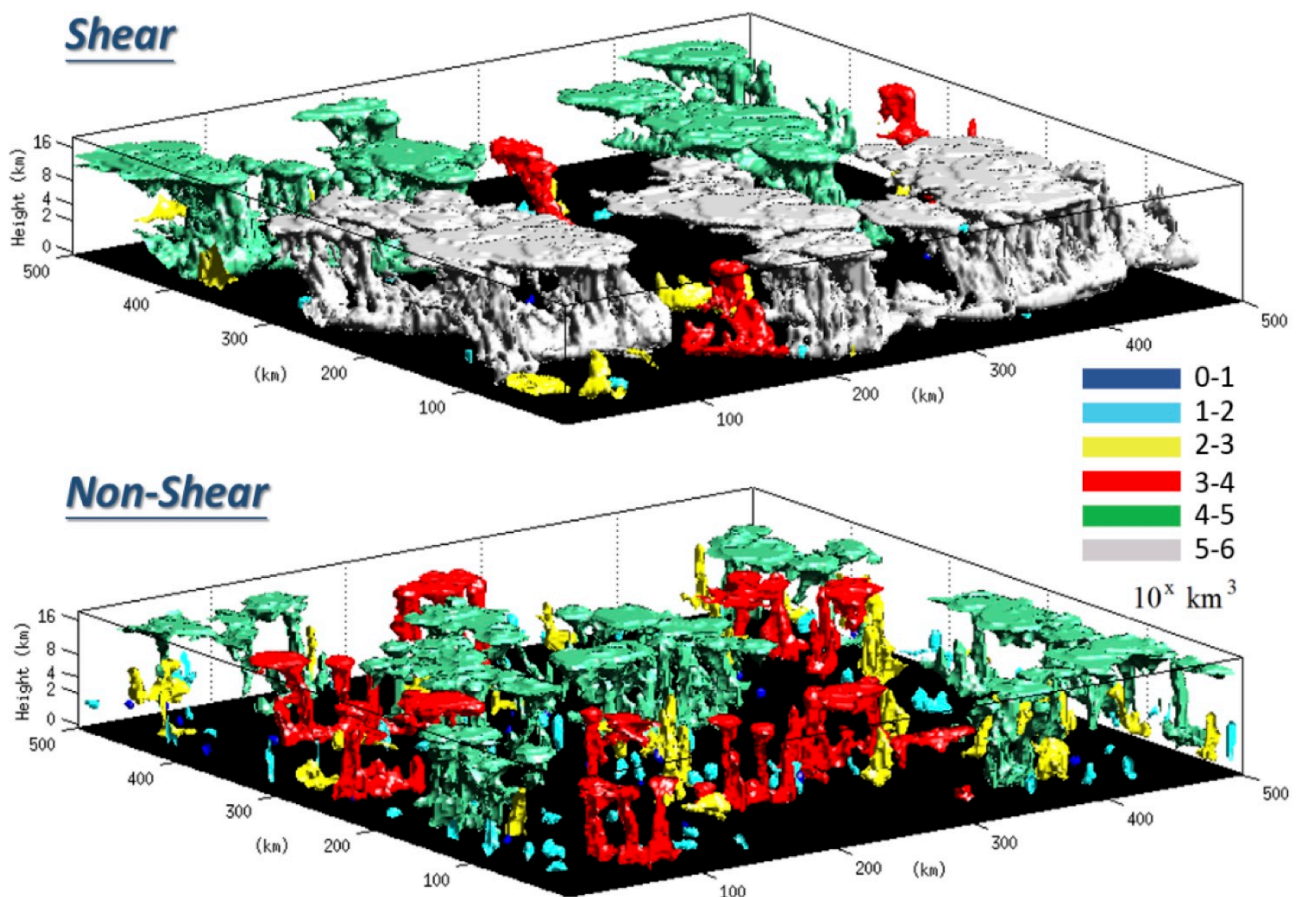
*Chien-Ming Wu¹, Wei-Ming Tsai¹

1. Department of Atmospheric Sciences, National Taiwan University

In this study, the environment of aggregated deep convection is investigated using a vector vorticity equation cloud-resolving model (VVM). Idealized experiments are performed under various environmental moisture with or without imposed vertical wind shear. Convective aggregation is then evaluated through diagnosing the 3-D size of an individual cloud from the model output using a six-connected segmentation method.

The aggregated convection is recognized by a distinct mode with larger size in the cloud size distribution. The results suggest that aggregated convection tends to develop when column relative humidity (CRH) is larger than 80% (67%) in non-shear (shear) cases. In addition, the degree of aggregation further increases with the increase of CRH. This aggregation process may be caused by an increasing probability of multi-cellular cloud structure under a moister environment. The results suggest that there are at least 5 core-updrafts of such system. Analyses of precipitation distribution suggest that the probability of extreme precipitation increases with the increase of aggregated convection. The favorable environment of aggregated convection can be used to improve convective parameterizations in large-scale models.

Keywords: cloud-resolving model, aggregated convection, extreme precipitation



Change in the horizontal scales of convection due to the self-aggregation of clouds under the radiative convective equilibrium

*松岸 修平¹、三浦 裕亮¹

*Shuhei Matsugishi¹, Hiroaki Miura¹

1. 東京大学 理学系研究科 地球惑星科学専攻

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

Idealized explicit convection simulations in radiative convective equilibrium (RCE) has been applied to research on tropical convection. Recent studies using three-dimensional cloud-resolving model in RCE conditions show convection can aggregate into a single region, when the domain is sufficiently large and the sea surface temperature (SST) is warm enough. The phenomenon is called as 'self-aggregation'. Convective organization modifies the mean vertical profiles of temperature, water vapor, and radiative fluxes. The mean climate change into dry and warm after self-aggregation occurs. Self-aggregation is sensitive to the SST, domain size, and horizontal resolution. Previous studies show aggregations favor relatively high SST and large domain size. However, these dependency is not clearly understood. In this study, we are attempt to determine the sizes of a moist region after aggregated and research the SST dependency of them.

We use SCALE-RM model which is non-hydrostatic cloud resolving model developed by RIKEN AICS. The horizontal spacing is 4 km, with 80 vertical levels. Simulations have a domain size of 512 km X 512 km with doubly periodic lateral boundaries, fixed incoming solar radiation. These were conducted in which SST was changed from 292 K to 310 K every 2 K. Self-aggregation occurs in SST over 304 K. The horizontal length scale is determined spatial autocorrelation is larger than $1/e$ about various two-dimensional variables. Horizontal scales about perceptible water, OLR lowest model level water vapo mixing ratio (Q_v) are about 200 km when aggregation occurs (SST is larger than 304K) in this study at all aggregate case. However, these about 35m (lowest model level) temperature decrease with increasing SST. In no aggregate cases, the same trend is observed. In these cases, scales of Q_v are about 30 km, but these of T are 30~100 km. Self-aggregation seems to be selected when Q_v and T scale are same. Furthermore, simulations with water vapor nudging with horizontal mean water vapor shows low troposphere humidity anomaly is important for self-aggregation. Furthermore, simulations with water vapor nudging with horizontal mean water vapor shows low troposphere humidity anomaly is important for self-aggregation. These results show self-aggregation depends on low troposphere and boundary layer process.

キーワード：自己組織化、放射対流平衡、対流

Keywords: Self-aggregation, RCE, deep convection

Statistics of Clusters of Tropical Convection as Simulated by a Global Cloud-Resolving Model

*Marat Khairoutdinov¹

1. Stony Brook University

Representation of moist convection on global scale remains challenging for global climate models (GCMs), which typically resolve scales much larger than individual clouds or even cloud clusters. With rapid progress in the supercomputer technology, several global cloud-resolving models have emerged over the past decade or so, with the premise to advance our understanding of the role of moist convection in regulating the Earth's climate system. A global version of a widely used cloud-resolving model (CRM), the System for Atmospheric Modeling (SAM), has recently been developed. The time and cost of development have been minimized by preserving most features and numerics of the SAM's existing anelastic non-hydrostatic dynamical core while generalizing it from rectangular to latitude-longitude grid. The main software challenge has been the development of efficient and highly scalable hybrid FFT-multigrid solver for elliptic equation for pressure. The model uses a single-moment bulk microphysics, comprehensive radiation transfer module, the Simplified Land Model (SLM) with 16 IGBP land types, single layer of vegetation, multilayered interactive soil, and a block representation of topography in the height coordinates. The preliminary results of multi-month global cloud-resolving simulations with a 4 km horizontal grid spacing at the equator will be presented. In particular, the statistics of convective clusters in the simulated Tropics and the diurnal cycle of precipitation over land and ocean will be discussed.

Keywords: global cloud-resolving model, convection, large-scale organization of clouds

The impact of simulated mesoscale convective systems on global precipitation and its characteristics

*Wei-Kuo Tao¹

1. NASA Goddard Space Flight Center

The importance of precipitating mesoscale convective systems (MCSs) has been quantified from TRMM precipitation radar and microwave imager retrievals. MCSs generate more than 50% of the rainfall in most tropical regions. Typical MCSs usually have horizontal scales of a few hundred kilometers (km); therefore, a large domain with several hundred km and high resolution are required for realistic simulations of MCSs in cloud-resolving models (CRMs). Almost all traditional global and climate models do not have adequate parameterizations to represent MCSs. Typical multi-scale modeling frameworks (MMFs) with 32 CRM grid points and 4 km grid spacing may also lack the resolution (4 km grid spacing) and domain size (128 km) to realistically simulate MCSs.

In this study, the impact of MCSs on precipitation is examined by conducting model simulations using Goddard Cumulus Ensemble (GCE) model, and Goddard MMF (GMMF). The results indicate that both models can realistically simulate MCSs with more grid points (i.e., 128 and 256) and higher resolutions (1 or 2 km) compared to those simulations with less grid points (i.e., 32 and 64) and low resolution (4 km). The modeling results also show the strengths of the Hadley circulations, mean zonal and regional vertical velocities, surface evaporation, and amount of surface rainfall are weaker or reduced in the GMMF when using more CRM grid points and higher CRM resolution. In addition, the results indicate that large-scale surface evaporation and wind feed back are key processes for determining the surface rainfall amount in the GMMF. Sensitivity tests with sea surface temperatures (reduced or coupled with ocean model) will be presented at meeting.

Keywords: Global Precipitation, Cloud resolving model, Multi-scale modeling framework, Mesoscale convective system