【Grant-in-Aid for Transformative Research Areas（B）】

Section II

Title of Project： Challenge to the new generation cloud-resolving climate simulation

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【Purpose of the Research Project】

In “Challenge to the new generation cloud-resolving climate simulation”, we will strive to bring about revolutionary advances to the climate science by the realization of the 6th generation climate model simulation, in which atmospheric phenomena are reproduced through spontaneous organization of clouds. Inclusion of explicit cloud microphysics schemes in addition to equations for atmospheric flows and radiation will enable models to reproduce clouds as physical entities with dimensions and will include spontaneous generation and dissipation of clouds. As a result, behaviors of aggregated cloud systems such as tropical cyclones and rainbands will be more realistically represented in the models. Moreover, this approach will eliminate low-order approximations and enable comprehensive evaluation of the cloud-radiation interaction, which is one of the most difficult aspects of climate predictions.

One of the distinctive characteristics of the atmospheric phenomena is their hieratical structure much similar to what is observed in biology. In analogy with the biological systems in which DNAs provide the blueprints for cells and organs, we perceive the cloud microphysics as the microscopic blueprints for the hierarchy of cloud systems. Thus, we entitled the novel approach to climate science with the 6th generation climate model that simulates cloud systems from cloud microphysics as DNA climate science.

【Content of the Research Project】

Taking advantage of the Earth Simulator launched in 2002 and K-computer launched in 2011, Japanese climate modeling groups have contributed to the Intergovermental Panel on Climate Change (IPCC) with the climate model MIROC and have led the world in the field of global cloud resolving modeling with a prototype of the 6th generation climate model, NICAM, for almost 10 years.

In this project, the plan A for realizing the 6th generation climate model is to modify the global cloud-resolving model NICAM to enable climate simulations, and back up with a plan B, in which we aim to add cloud-resolving processes on to MIROC. We aim to enhance cooperation between the developers of NICAM and MIROC so that the two models can complement each other to connect the intraseasonal time scales of typhoons and MJO and the longer timescales of Asian monsoon and climate, which NICAM and MIROC respectively excel in. Furthermore, aiming at the 7th generation standard, young researchers will take the lead in research for advanced modeling, such as general-planet model that positions the Earth as one of the planets and calculates flow phenomena of gas, liquid, and solid phases of the planetary surface layer, and a multiple-hierarchical model that dramatically increases parallel computing efficiency by incorporating the intrinsic hierarchical nature of fluid phenomena.

【Expected Research Achievements and Scientific Significance】

With the rise of exascale computers in sight, the development of the 6th generation climate models is in full swing in Europe and the United States and is expected to become the norm of climate predictions within a decade. This will lead to a paradigm shift from estimating the effects of clouds on climate from hypothetical clouds to the direct analysis of realistically reproduced clouds. This will contribute to resolving the grand challenges set by the World Climate Research Program (WCRP).

Furthermore, by providing more reliable climate predictions, we will contribute to solving global-scale issues such as the SDGs (Sustainable Development Goals) set by the United Nations. The WCRP has identified Digital Earths (a digital twin of the Earth) as one of the Lighthouse Activities that identify the core issues for the next generation climate science. Our research project is also in line with this global trend toward the realization of the Digital Earths.

【Key Words】

Climate model: A program consisting of several hundred thousand lines that computes equations for fluid dynamics, thermodynamics, and optics that are associated with the energy and water budgets of the atmosphere, land, and the oceans.

The 6th generation climate model: An interpretation of the generations of the models as 1st generation (1970’s) as 1D radiative-convective equilibrium model with static clouds, 2nd generation (1980’s) as 3D atmosphere general circulation model, 3rd generation (1990’s) as an atmospheric model coupled to a static ocean, 4th generation (2000’s) as atmospheric model coupled to 3D ocean circulation model, and 5th generation (2010’s) as the modern climate model that includes atmospheric chemistry and carbon cycle processes.

【Term of Project】 FY2020-2022

【Budget Allocation】 122,000 Thousand Yen

【Homepage Address and Other Contact Information】

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