Press Releases

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Japan Agency for Marine-Earth Science and Technology
Atmosphere and Ocean Research Institute of The University of Tokyo

Global Cloud Resolving Model Offers Great Promise in Projecting Tropical Cyclone Activity in Global warming

Overview

Global warming conditions reduce the number of tropical cyclones globally but increase that of intense category, according to a model projection of tropical cyclone (TC) activity using a global cloud-system-resolving model (GCRM), an atmospheric model capable of directly calculating lifecycle of cloud clusters.

The model experiment, run on the Earth Simulator, was the first attempt to use the GCRM to gain insight into the TC change in response to global warming (GW). The simulated results were consistent with the findings in the 4th Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC).

The study was led by Kazuyoshi Oouchi, Research Scientist, and Yohei Yamada, at the Japan Agency for Marine-Science and Technology (JAMSTEC) and Masaki Satoh, Research Scientist at JAMSTEC, and Associate Professor at the Atmosphere and Ocean Research Institute, The University of Tokyo.

The experiment also revealed higher cloud-top heights in more intense TCs under the GW condition. Conventionally, the frequency and intensity of TCs have been discussed using numerical models unable to handle cloud clusters (*2) directly, which has been the source of major uncertainty in climate response. The Nonhydrostatic ICosahedral Atmospheric Model (NICAM)(*1), a prototype GCRM, on the other hand, can explicitly represent cloud clusters, enabling scientists to obtain more reliable simulation output.

The model results demonstrated significant skills of NICAM in projecting future changes in TC activity in response to a given climate change for the first time in the world, creating a new avenue for climatic modeling.

The study was conducted as a part of the "Improvement of cloud-precipitation systems for climate simulations using a global cloud-resolving model", a program adopted under the government's Innovative e Program of Climate Change Projection for the 21st Century (*3), as well as under the

Core Research for Evolutional Science and Technology (CREST)(*4) program by the Japan Science and Technology Agency(JST).

The work was published in the April 8th issue of the U.S. journal Geophysical Research Letters, and will appear in the April 22nd issue of the U.K. journal Nature, as a “Research Highlight” article.

Title: Projection of changes in tropical cyclone activity and cloud height due to greenhouse warming: Global cloud - system - resolving approach, Geophys. Res. Lett., 37,L07709, doi:10.1029/2010GL042518.

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Background

The IPCC AR4 reported that the climate warming would increase the intensity of tropical cyclones, while storm frequency would decrease globally. However, Chapter 8 of AR4, “Climate Models and Their Evaluation”, suggests that the projection of the decrease in TC number is somewhat unreliable.

The above estimates were based on the study by JAMSTEC, which was performed on the Earth Simulator using a high-resolution AGCM for the time. The AGCM, however, was not able to directly resolve cloud clusters, a key element in simulating TC motion and structure, and thus involved considerable uncertainty in projection.

NICAM, in contrast, is capable of reproducing the convective features of cloud clusters realistically. It allows for the detailed and reliable representation of TC genesis and related cloud formation, as well as atmospheric phenomena and circulation in areas conductive to TC formation. NICAM can calculate, not only the cloud features associated with TC, but also the changes in the frequency and intensity of TCs in response to GW far more accurately than any other climate models. Needless to say, simulations with this new model require enormous computational power, which was made possible by the outstanding performance of the Earth Simulator.

Experiment design

To bring about dramatic progress in atmospheric models, JAMSTEC and Tokyo University have been developing a high-resolution AGCM capable of directly treating atmospheric circulation and the formation and dissipation of clouds, using the Earth Simulator. With this model, experiments were carried out for two simulation runs: a control (CTL) run for the present-day climate using the atmospheric data and SST from June to October 2004; and a global warming run for the future climate from May to October at the end of the 21st century.

For the latter, the model was forced with boundary conditions of greenhouse gasses and sea surface temperature (SST), and run for 6 months including a one-month spin-up period for the model. Carbon dioxide concentrations were given based on the IPCC's Special Report on Emissions Scenarios (SRES) A1B, which predicts that the CO2 concentrations would double at the end of the 21st century. SSTs were prescribed by adding the SST difference between the future and present-day climates from the CMIP3 multi-model dataset (*5) onto the SST in CTL.

Results

The frequency distribution of TCs by maximum wind speed and minimum surface pressure (Fig. 1), showed the increased occurrence of more intense TCs (with greater wind speeds and lower minimum pressures) in GW. In both cases, the cloud height becomes taller with the increase in TC intensity, but this tendency is more evident in GW (Fig. 2).

Future perspectives

The study revealed for the first time the projection of TC activity change due to global warming, by use of the global-cloud-system resolving model, NICAM. It is an important scientific advance because the high-resolving simulation by NICAM has successfully yielded results that support the IPCC AR4 report regarding changes in TC frequency and intensity. These climate variables are among the most pressing concerns for local societies and economies.

The use of this model can also eliminate the uncertainty inherent to simulating clouds by climate models, a scientific challenge in TC projections as reported in the IPCC AR4, and allowed scientists to directly discuss the changes in clouds forming TCs. Understanding the clouds and precipitation changes within TCs will enable them to deliver a more quantitatively reliable rainfall projection.

The NICAM has created a new pathway for climate projection by exploring changes in TC activity and its surrounding climate conditions. With further improvements in computational skills that allow for a longer integration period (years), the NICAM simulation will capture not only global trends in TC activity change, but also those for specific oceanic regions.

Gaining insight into future climate trends is becoming an increasingly urgent task for alleviating the possible adverse impacts of climate change. Access to the next-generation high-performance computing resources in the future will further advances in science and research using NICAM.

***1 Nonhydrostatic ICosahedral Atmospheric Model**
NICAM is the world's first global atmospheric circulation model (AGCM) capable of directly calculating the formation and dissipation of clouds. Conventional AGCMs simulate relationships between atmospheric circulation and clouds under assumptions, which is a major uncertainty in the atmospheric modeling. NICAM can treat the direct response of clouds to the atmospheric circulation, allowing for calculations with greater precision.

***2 Cloud cluster**
A group of cumulonimbus clouds that looks like a large mass of cloud in satellite images due to their successive generation. Cloud clusters are more

often observed in the tropics, extending horizontally for several tens to several hundreds of kilometers. The interaction of clusters with the convection, waves and circulation of the atmosphere results in tropical cyclones. They form a ring of deep clouds and spiral cloudbands around the cyclone eye.

***3 Innovative e Program of Climate Change Projection for the 21st Century**

Response to climate change events is a topic of international and political importance and of significant interest for the awareness in the Japanese society. The Innovative Program of Climate Change Projection for the 21st Century, sponsored by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), supports scientific teams pursuing extremely reliable and high-resolution projections on climate change. It also aims to promote research into impact assessment of natural disasters by analyzing extreme events such as typhoons and localized torrential downpours. The simulation results are expected to contribute to the upcoming IPCC Fifth Assessment Report (AR5).

***4 Core Research for Evolutional Science and Technology (CREST)** is designed to promote the MEXT's strategic scientific goals to meet the nation's societal and economic needs. It funds a team of researchers and supports their studies of scientific and technological significance.

***5 Coupled Model Intercomparison Project World phase 3 (CMIP3) multi-model dataset**

A data set provided by Coupled Model Intercomparison Project (CMIP), a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models.

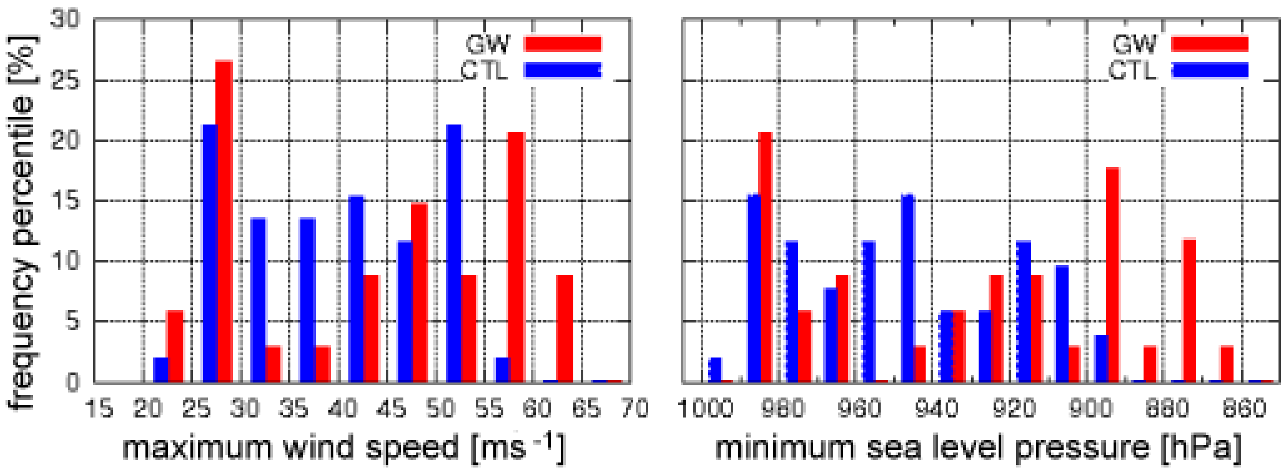

Figure 1. Frequency percentile by maximum wind speed (left) and minimum surface pressure (right). Blue bars denote TCs in CTL and red bars for those in GW. More intense TCs, with greater maximum wind speeds and lower minimum surface pressures, occur in GW.

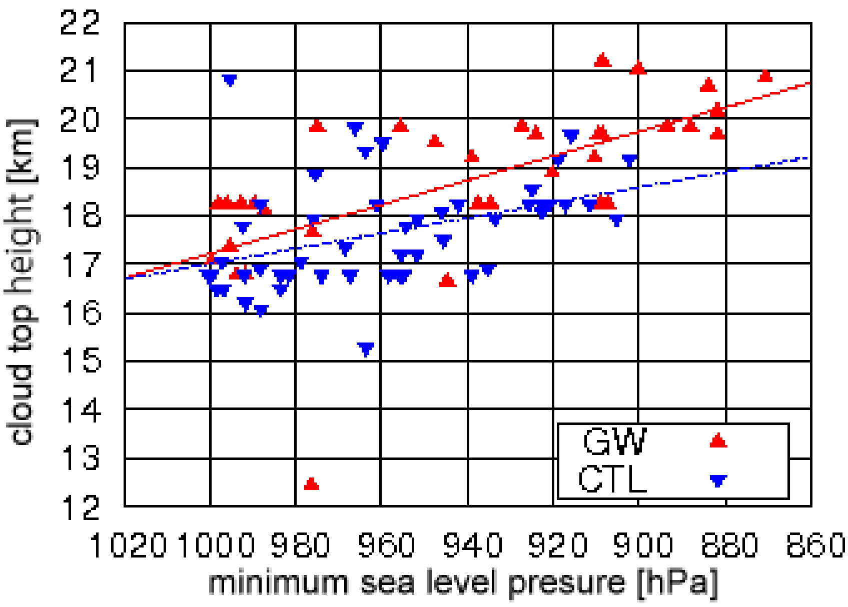

Figure 2. Scatter plots for the cloud top height and the minimum surface pressure (MSP) for the simulated TCs, and the regression lines for CTL (blue broken line) and GW (red solid line). Cloud heights are greater in GW than in CTL.

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