Research on Global Warming Prediction by using the High-Resolution Atmosphere-Ocean Coupled Model

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Coupling effect of atmosphere and ocean models with different horizontal resolution has been investigated. Three AGCMs (T213L56, T106L56, and T42L20) and two OGCM (1/4 degree × 1/6 degree L48 and 1 degree × 1 degree L44) are coupled each other and their performances are compared. In any coupling, there is no climate drift. This suggests that when each model is well tuned in energy and mass balance, climate-drift may not happen when it is coupled each other.

By using these models, Kuroshio around Japan was investigated. The Kuroshio tends to flow northward when the medium resolution model is used. It is shown that the high resolution ocean model is necessary for simulating the Kuroshio separation around Japan. Resolution of the atmospheric component is also important. When the resolution of AGCM is low, the variability of the Kuroshio becomes larger. It is suggested that proper resolution for both atmosphere and ocean components is necessary.

Effectiveness of the time-slice method is also investigated. It is demonstrated that when AGCM is integrated without an air-sea interaction, more energy and water is supplied from the ocean. Therefore, results tend to show more precipitation and warmer temperature over land. However, the difference is not so large and qualitative conclusion so far obtained seems to be acceptable.

Keywords: climate model, resolution, Kuroshio, global warming, atmosphere-ocean coupling

1. Introduction

In 2005 fiscal year, analysis on simulation results conducted in 2004 fiscal year and model development have been conducted. For model development, effect of resolution of atmospheric and ocean components has been investigated. Then, the effectiveness of the time-slice method has been investigated by using the high-resolution climate model results.

2. Effects of the horizontal resolution of atmospheric and oceanic component models in the climate model

In order to investigate an impact of horizontal resolution in atmospheric and oceanic components, an coupled model system, where component models with different resolution can be interchanged, has been developed. Atmospheric component models are T213L56 (denoted to be uA), T106L56 (hA) and T42L20 (mA), and oceanic component models are 1/4 degree × 1/6 degree L48 (hO) and 1 degree × 1 degree L44 (mO). Hereafter, a coupled model with T213L56 and 1/4 × 1/6 L48 is shown as uAhO. Time integrations have been conducted under the present climate condition (see Table1). In any coupling, we can simulate well the present climate without any flux adjustment. When each component model is well tuned in energy and mass balance, it is shown that interchange of components does not cause a climate drift. It should be noted that most of physical processes are common in each component model.

In Fig. 1, differences of annual mean SST between observation (1961-90) and model simulation are shown. In general, the differences are within 1~2°C. Although time integration period is not sufficient, the RMS difference is minimum in uAhO and it is expected that performance of the climate model can be improved by introducing high resolution component models.

Table 1 Details of coupled models

models	Initials	Period of integration
uAhO	A certain time of hAhO model integration	28years
uAhO	Several tens of year integrated state from observed SST and Sea-ice	100years
mAhO	A long-term integration of hAhO model	40years
hAmO	Same as above	90years
mAmO	Several hundreds of year spin-upof thecoupled model after about 2000 year spin-up of OGCM only.	More than 2000years

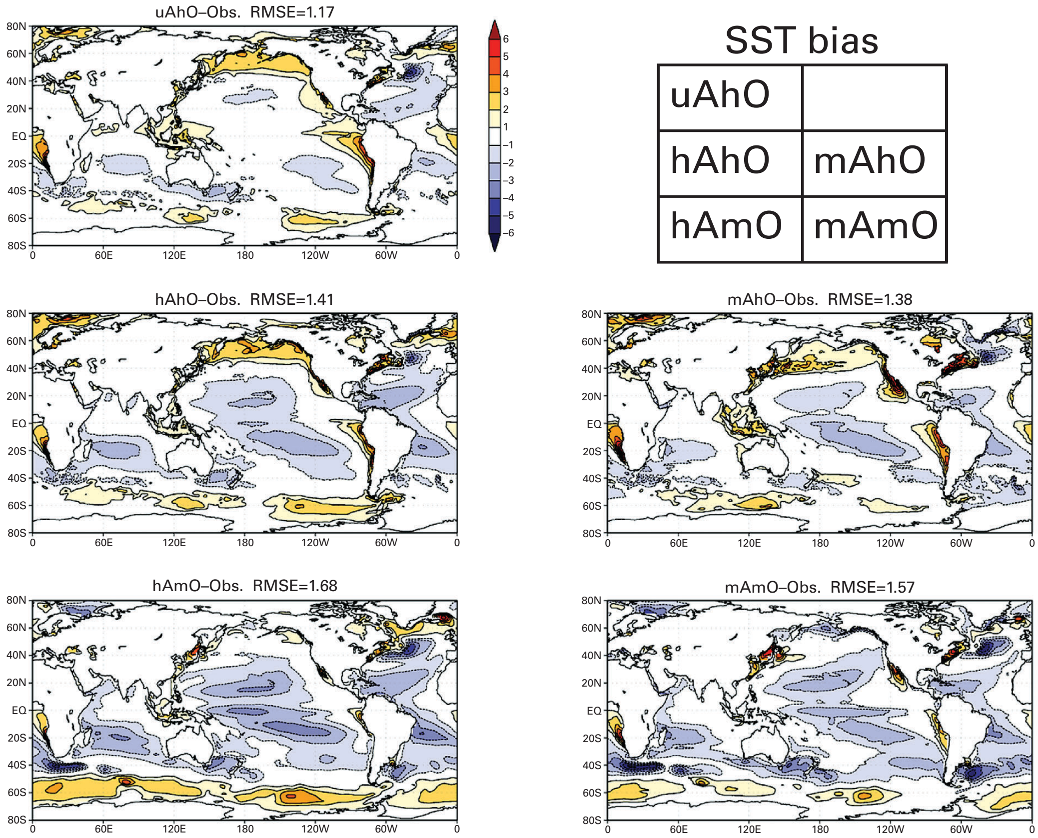

Fig. 1 Differencesof the annual mean SST between the observed values (1961-1990) and simulations (°C). Period of model integrations are shown in Table 1.

Then, performance of the Kuroshio around the Japan Island is investigated. In Fig. 2, long term averaged SSTs and currents at 100 m depth are shown. When the medium resolution OGCM is used, the width of the Kuroshio becomes wider and tends to flow northward. This is shown in mAmO and hAmO. On the contrary, the Kuroshio current and location of the Kuroshio separation are well represented in hAhO and mAhO. These results are consistent with previous results.

However, when hAhO and mAhO are compared, the difference can be noted. The location of the Kuroshio separation is shifted slightly northward in mAhO than in hAhO. Furthermore, it is shown that the variability of the location of the Kuroshio separation is larger in mAhO.

In summary, a high resolution OGCM is indispensable in representing the Kuroshio current, but resolution of atmospheric models is also very important. What kind of combination is good is the future topic.

3. Effectiveness of the time-slice method

In order to conduct downscaling, a fine resolution AGCM is integrated by giving SST distribution computed by the coarse atmosphere-ocean coupled model. This method is called a time-slice method. However, it is not yet evaluated to what degree this method is accurate. In our case, we have conducted the simulation of the high-resolution climate model. Then, we have integrated the atmospheric component model by giving the SST obtained by the coupled model (denoted to be AGCM-run, and the coupled model run is denoted to be CGCM-run). The simulation period is the northern summer period (June-August). It should be noted that the atmospheric component model is the same and the daily-averaged SST is common in both run. Only difference is a transient atmosphere-ocean interaction.

As an air-sea interaction does not work in AGCM-run, more energy and moisture are supplied in the AGCM-run. Then, surface temperature over the land region tends to be larger in AGCM-run than in CGM-run. It is suggested that this is due to the increase of the downward long-wave flux, because the moisture in the atmosphere is increased.

In summary, it is shown that there exists a systematic bias in evaporation in the time-slice method. This causes an increase of rainfall and surface temperature over the land area. Its effect is not so large, but 20% increase of the dates of more than 20 mm/day around Japan is shown. When we apply the simulation results to the application issue, we should note this difference (see, Fig. 3).

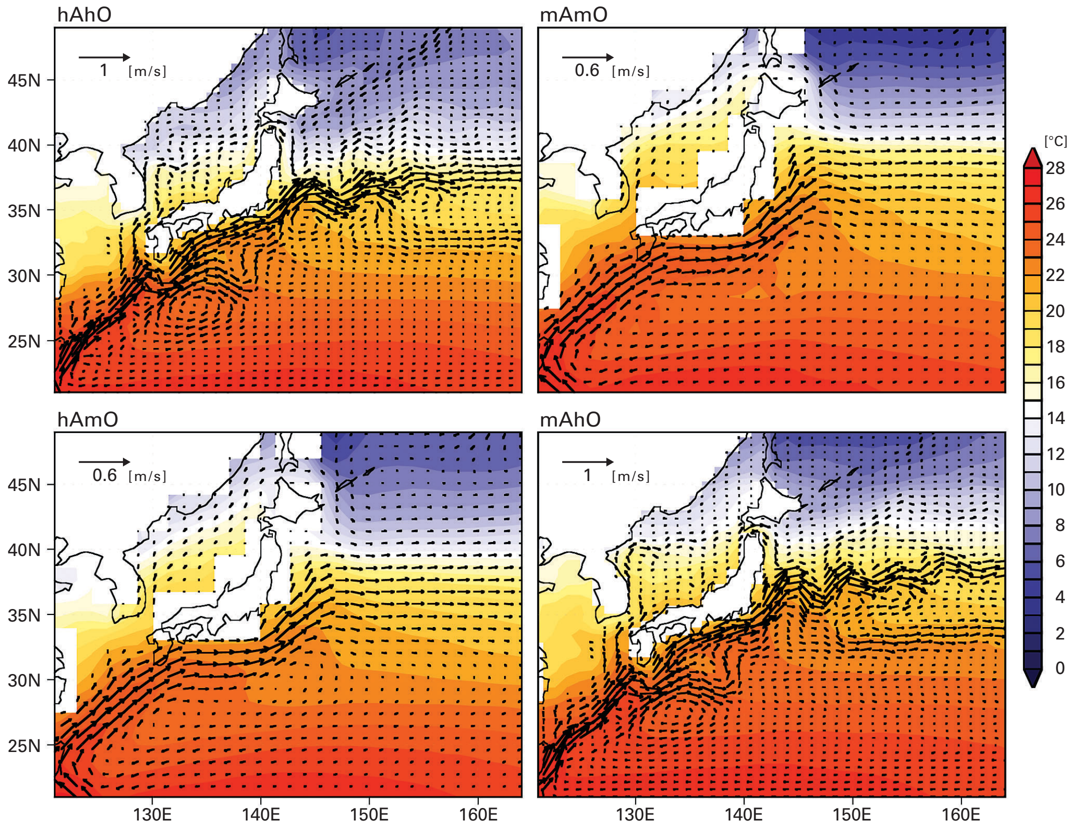

Fig. 2 Averaged SST and currents at 100 m depth.

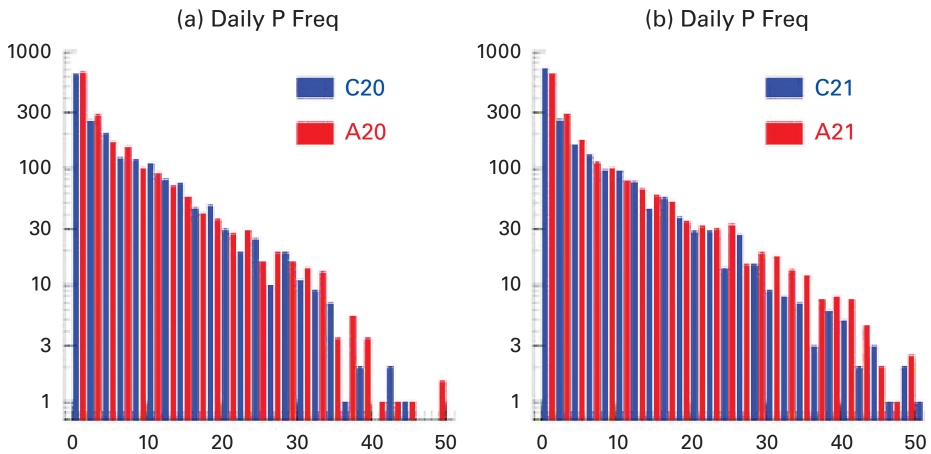

Fig. 3 Frequency distribution of daily precipitation around Japan (130-138E, 32-38N).
AGCM-run is shown in red and CGCM-run is shown in blue. (a) represents the present climate and (b) represents the global warming climate.

高分解能大気海洋モデルを用いた地球温暖化予測

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2005年度は、前年度行った計算結果の解析、および、論文執筆、そして、次につながる気候モデルの高度化を行った。気候モデルの高度化では、高分解能大気海洋結合モデルの性能を確定させるために、もう一段高分解能の大気モデルを結合させて計算をおこなった。また、大気海洋結合系モデルと、その計算された海面水温を与えた大気モデルの計算を行い、タイムスライス法の有効性を吟味した。

大気海洋双方における解像度のインパクトを明らかにするために、大気、海洋の高解像度、中解像度版を互いに差し替えたモデルシステムを構築し、現在気候再現実験（コントロール実験、正確には1900年時点（中解像度版大気は1850年）の気候条件で行った）を行った。大気モデルは、T213L56モデル（uAと呼ぶ）、T106L56モデル（hA）、T42L20モデル（mA）、海洋は、1/4度 × 1/6度L48のモデル（hO）と1度 × 1度L44のモデル（mO）である。大気海洋のあらゆる組み合わせにおいて（たとえば、高分解能気候モデルは、hAhOと表される）、人為的なフラックス調整なしで、ドリフトのない良好な現在気候を再現することができた。これまで、大気海洋結合気候モデルにおいてはドリフトを避けるための調整が課題とされてきたが、大気海洋双方で慎重なチューニングを行うことにより、安定な気候を再現できることが示された。なお、大気海洋の物理過程は、解像度に依存するものと系全体の放射収支を合わせるための雲パラメータの一部を除いてどのモデルでも共通している。

各バージョンの年平均海面水温気候値の観測（1961-90年平均）との差（バイアス）は、全球平均でおおむね1~2°Cに収まっている。積分期間がまだ十分ではないが、根二乗平均バイアス（各パネルの上段に表示。単位°C）は、もっとも解像度の高いuAhOで最も小さくなっており、高解像度化による気候再現精度向上に希望を抱かせる結果となっている。

続いて、これら4つのモデルの標準実験の結果を用いて、黒潮の表現がどのように異なるのかを調べてみた。その結果によれば、黒潮を適切に表現するには海洋の高解像度化が不可欠であるものの、結合している大気の解像度によっては黒潮の離岸が適切に表現されない恐れがあることが示唆された。大気の解像度が黒潮の離岸にどのように影響を与えているのかについては、現在解析を進めている段階である。

キーワード：地球温暖化, 高分解能気候モデル, 黒潮, 大気・海洋結合モデル