Development of A High Resolution Climate Model by Using the Earth Simulator

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A high resolution climate model has been developed jointly by CCSR, NIES and FRSGC. It is a coupled system between the CCSR/NIES AGCM and COCO. The atmospheric component is a T106L56 spectral model and the OGCM is a 1/4 degree by 1/6 degree L48 grid point model. A sea ice model and a river run-off model are included. Especially, the direct and the first and second kind of the indirect effect of aerosols are included.

The version 0 model was fixed at June 2003, and the test run was conducted. 40 year time integration was finished and the results were examined. As we decided no use of "flux-correction", it was worried that climate-drift may occur. However, the model has no climate-drift. The main reason is because we have spent a lot of time to maintain a radiational balance in the model.

Improvements in the large-scale and regional-scale features are noted. For example, the simulation of the Baiu-front is improved. Especially, improvement in the moisture fields is noted because of increasing horizontal resolution and vertical levels. Interestingly, the SST and wind fields around the Hawaiian Islands recently found by Xie et al. (2001) are well reproduced. This is considered to be due to the high resolution model.

An 1% CO2 increase run was also conducted for 40 years. By comparing this field with the control run, it is demonstrated that the regional climate change can be simulated by the high resolution climate model. More research on the regional climate change is necessary.

Finally, after several corrections and tuning were conducted, the version 0 model was improved to be the version 1 model. Spin-up run by using this model was conducted.

Keywords: climate model, global warming simulation, regional climate change, high-resolution, far-reaching effet of the Hawaiian Islands

1. Summary of the 2003 fiscal year

CCSR (Center for Climate System Research), NIES (National Institute of Environmental Studies) and FRSGC (Frontier Research System for Global Change) has established a research consortium and has been developing a high resolution climate model since 2002. It is a coupled system between the CCSR/NIES AGCM (Numaguti et al., 1997) and COCO (CCSR Ocean Component Model). The atmospheric component is the T106L56 global spectral model and the OGCM is the 1/4 degree by 1/6 degree grid point model with 48 levels. A sea ice model and a river run-off model are included. Standard physical processes are included. Especially, it should be noted that the direct and the first and second kind of the indirect effect of aerosols are included.

In the first quarter (April–June), the model developed at 2002 was re-tuned and improved. Then, the version 0 of the climate model was freezed at July and the control run was started at August. Even though the Earth Simulator has huge computer capability, it is not easy to conduct long time-integration by using the high resolution climate model. 40 year time integration was completed until October. As we decided that "flux-correction" is not used, it is worried that climate drift may occur. Fortunately, the model did not show any climate drift. This is considered to be due to the careful treatment of the model to achieve the radiational balance.

Careful examination of the control run was conducted. Many improvements in the large-scale and regional-scale features are noted. Brief summary will be presented in section 2.

An 1% CO2 increase run was also conducted for 40 years. By comparing these results with the control run, it is suggested that regional climate change can be represented. However, there exist other methods to investigate the regional climate change. Each method has its own advantage and disadvantage. Careful research on these aspects should be conducted further.

As climate sensitivity of the model seems to be high, the time integration was terminated at year 40. Then, we tried to reduce the climate sensitivity. We found that we can reduce the climate sensitivity by changing parameters controlling cloud processes.

At the fourth quarter the version 0 model was improved to be the version 1 model, which will be used for IPCC runs. A spin-up run was being conducted.

2. Performance of the version 0 model

Fig. 1 (top) shows a time sequence of the globally averaged surface temperature and Fig.1 (bottom) shows sea-ice contents at the Arctic (blue line) and the Antarctic (red line) regions. These values are considered to represent a balance state of the climate model. During the first 17 years, minor modification of parameters was conducted. Since then, the model shows stable situation. In Fig. 2 sea-ice distributions in the Arctic region are shown. Winter and summer distributions are well simulated. Fig. 3 shows the sea-ice distribution in the Antarctic region. Again, the distribution seems to be reasonably corresponding to the observed distribution. It is concluded that the model has no climate drift.

Fig. 4 shows an annual average of observed SST (Sea Surface Temperature) and simulated SST. Although there are some discrepancies, both fields are reasonably similar. We can say that the model can well reproduce the present climate state.

Fig. 5 displays the annual mean of precipitation. The Baiu front is well simulated in the model. It is noteworthy that representation of moisture fields is improved. This is considered to be an increase of vertical horizontal and resolution in

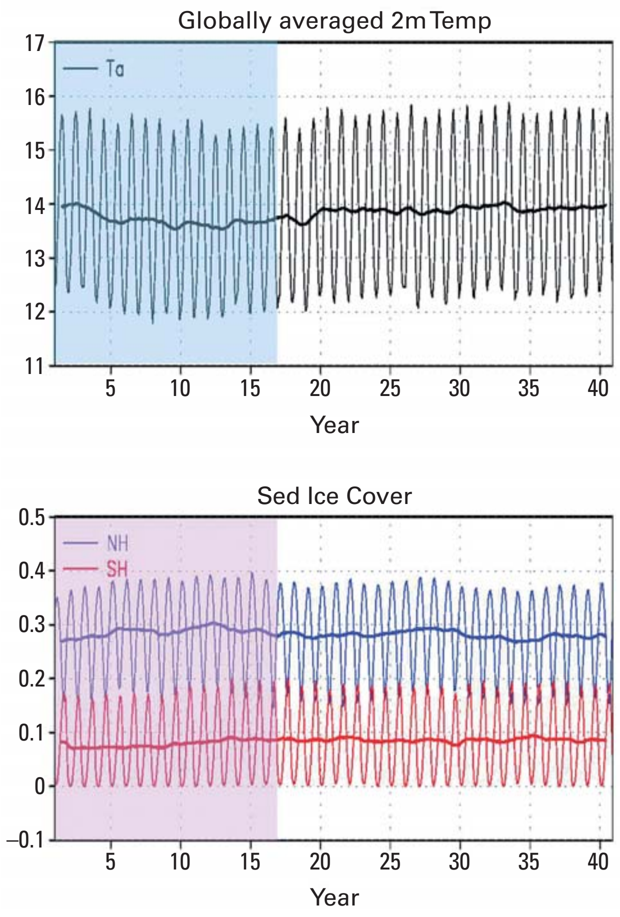

Fig. 1 (Top) the globally averaged surface temperature of the climate model. (Bottom) the sea-ice distribution at the Arctic region (blue) and the Antarctic region (red).

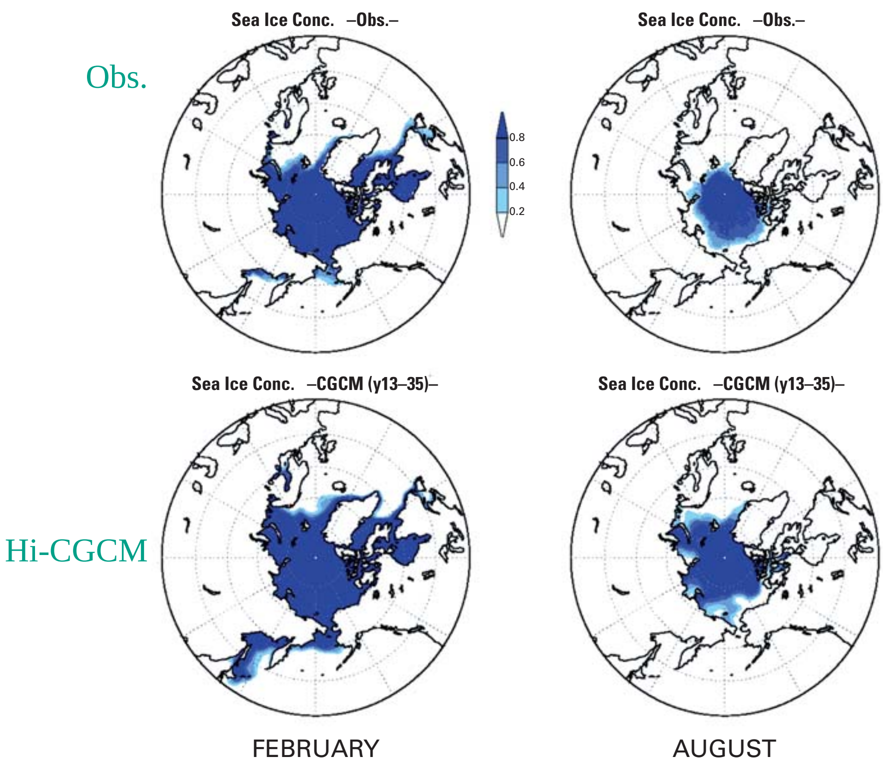

Fig. 2 The sea-ice concentration in the Arctic region. (Top left) the observation at February and (top right) August. (Bottom) The sea-ice concentration simulated by the climate mode.

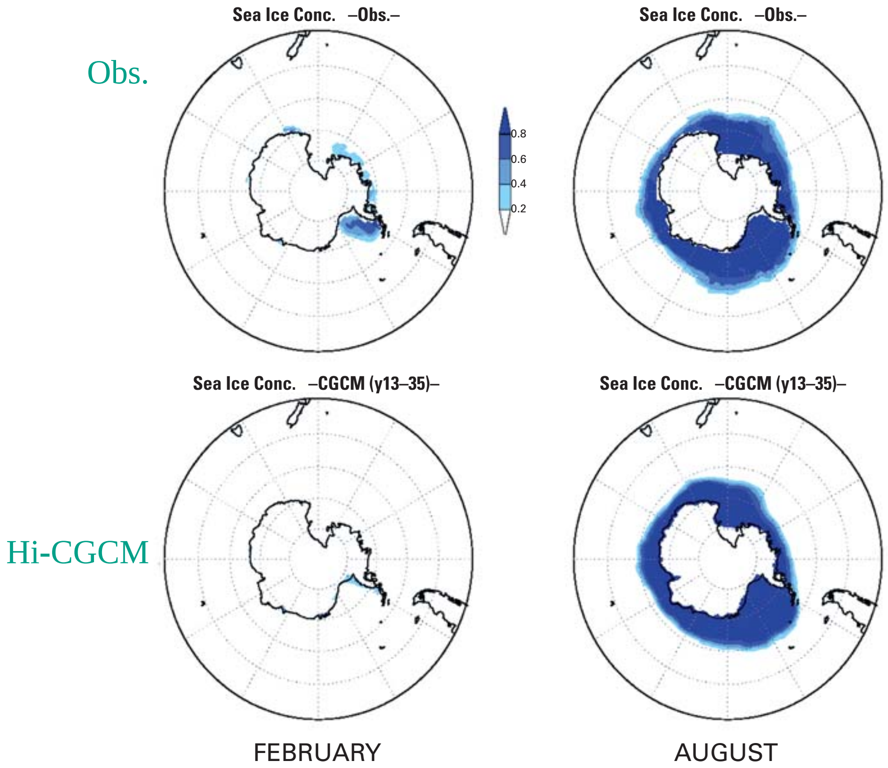

Fig. 3 Same of Fig. 2, except for the Antarctic region.

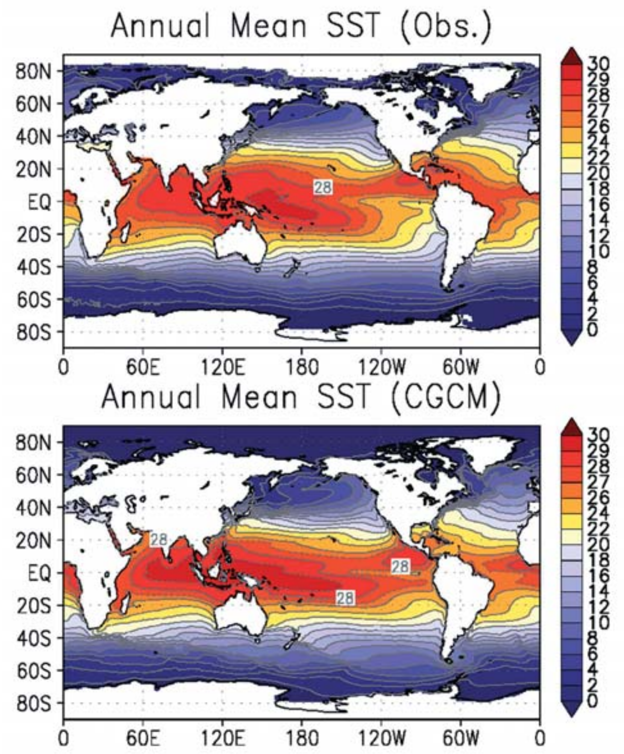

Fig. 4 (Top) the observed annual mean of SST. (Bottom) the simulated annual mean of SST.

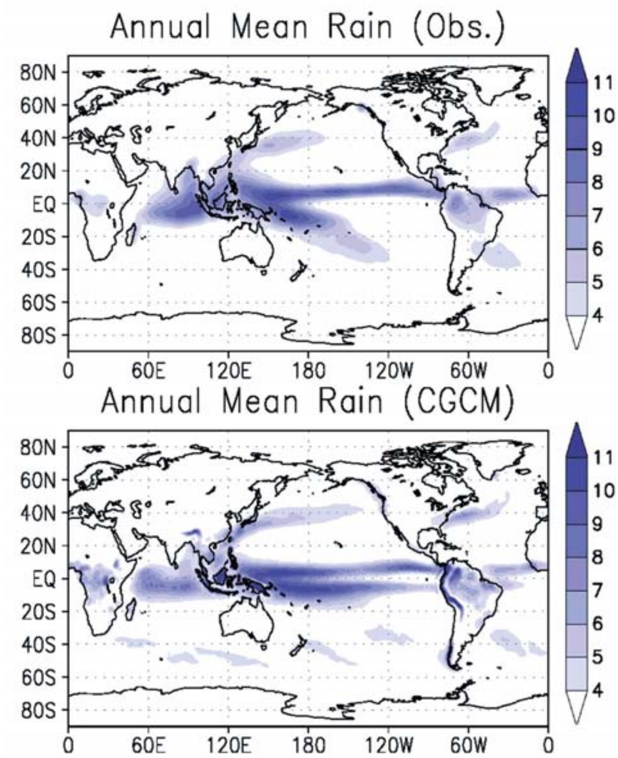

Fig. 5 Same of Fig. 4, except for the precipitation.

AGCM. Although there are many improvements, there exist many problems, one of which is a double ITCZ structure in the eastern tropical Pacific region. This bias is common to many models and further investigation will be necessary.

As we use the high resolution model, representation of regional phenomena is considered to be improved. One example is shown in Fig. 6. Recent observation study (Xie et al., 2001) showed the far-reaching effect of the Hawaiian Island to SST and wind fields. These features are well reproduced in the model simulation, which cannot be reproduced without representing the Hawaiian Islands.

An 1% CO2 increase run was also conducted. By compar-

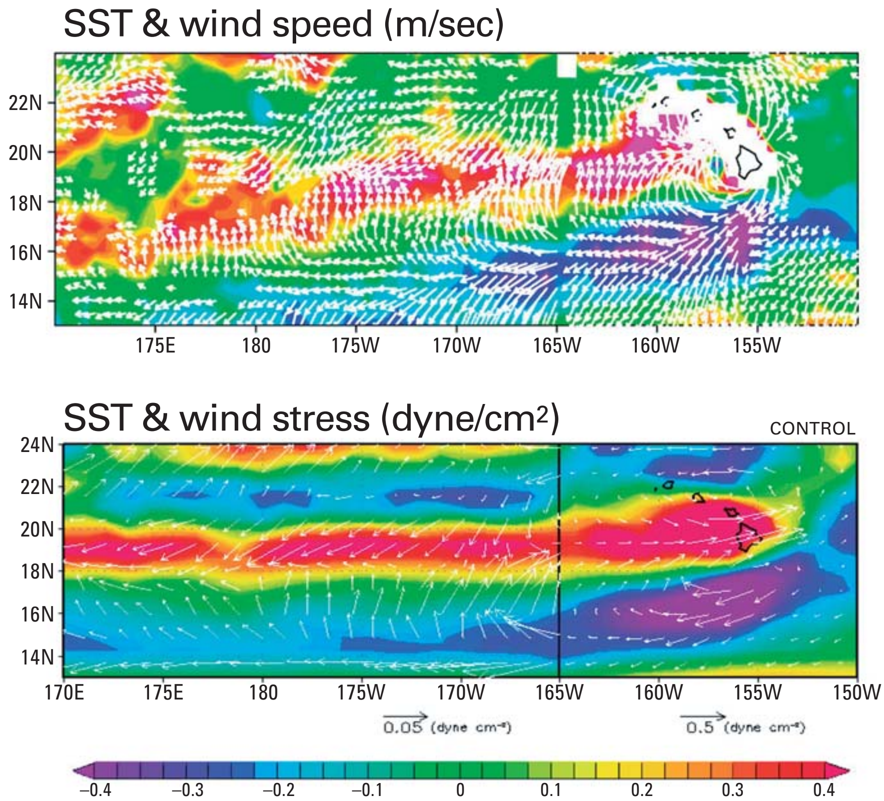

Fig. 6 (Top) Observed far-reaching effect of the Hawaiian Island in the SST and wind field (Xie et al., 2001). (Bottom) the corresponding field simulated by the model.

ing the results with the control run, we estimated the possibility for representing regional climate change due to the global warming. It is demonstrated that the regional climate change is represented. However, there exist other methods for representing the regional climate change, that is, a regional climate model and a time-slice method. Each method has its own advantage and disadvantage. How to use these methods in order to represent the regional climate change is a future research topic.

3. Future direction

As the climate sensitivity of the version 0 seemed to be high, the time integration was terminated at year 40. Based on our experience, we could reduce the climate sensitivity by changing parameters in cloud processes. At the same time, an on-line aerosol model was plugged in the model. The version 0 model was converted into the version 1 model, which will be used for IPCC AR4.

At the same time, we are developing a medium-resolution climate model with the same physics to the high resolution climate model. Our strategy is an integral use of these two models for the IPCC scenario runs. That is, the high resolution model is used to validate a model performance and the medium resolution model is used to investigate many cases.

References

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