PROJECTION OF THE CLIMATE CHANGE FOR ASIA REGION WITH THE HIGH-RESOLUTION AGCM BASED ON THE RCP SCENARIOS

PROIEZIONE DEL CAMBIAMENTO CLIMATICO PER LA REGIONE ASIA CON L'AGCM AD ALTA RISOLUZIONE BASATA SU SCENARI RCP

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Abstract
The high-resolution GCM has been used for regional detail climate response to observed CO_2 and other greenhouse gases for the future climate simulation. For this, we have adopted a high-resolution GCM which is based on uniform icosahedral-hexagonal grid. We have performed the present-day climate simulation during 1979-2009 years using AMIP observed SST and Sea Ice Concentration and subsequently we have performed the future climate simulation from 2010 to 2030 years from 4 CMIP5 model's boundary data based on two RCP scenarios (RCP 8.5 and RCP 4.5) by IPCC AR5.
The model can reflect the detailed trend of seasonal precipitation and 2m temperature over the Asia by the better representation of topographical effects. In next 30 years's near future, it shows the increase of 2m temperature over the Asia region. Although it is not able to capture accurately the response of regional climate change, it can provide the regional information for future climate change of the worldwide.

Keywords: icosahedral-hexagonal grid, GME, Climate Simulation, RCP scenario.
Parole chiave: griglia icosaedrica-esagonale, GME, Simulazione del Clima , scenario di RCP.

Introduction
Climate change has caused the large casualties and economical losses in the world and it will continue for centuries. Understanding and predicting the Climate change are so important to respond the adaption policies that many climate modeling groups are participated the climate research. But, users of climate results produced by global climate models with coarse grid-spacing have a lot of dissatisfactions with the insufficient mismatch of spatial scale in particularly area with complex terrain like East Asia region. The various downscaling techniques have been conventionally used to obtain the climate scenarios with local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses. Among these methods, the regional downscaling is used in a lot of research activities, but it has a limitation from lateral boundary conditions. Compared with this, global downscaling method can avoid the lateral boundary problems. So In this study, we suggest the climate simulation using atmospheric global climate model with horizontally high-resolution grid.

Materials and Methods
The atmospheric GCM used is an operational global numerical weather prediction model GME (Majewski et al., 2002) of German Weather service. It is based on uniform icosahedral–hexagonal grid. This gridpoint approach avoids the disadvantages of spectral techniques as well as the pole problem in latitude-longitude grids and provides a data structure extremely well suited to high efficiency on distributed memory parallel computers. For long term simulation, mass correction was applied in GME (Chaudhari, 2006). In this study, we adopted the high resolution of GME with 40-km/40 layers. In 40-km mesh size, the number of gridpoints is 368,642 and transform grid uses 900 X 451 grid cells. Detailed description of the model is given in Majewski *et al.* (2002).
We have performed the present-day climate simulation from 1979 to 2009 with the historical sea surface temperature (SST) and Sea Ice concentration observation data of AMIP. And for the future climate simulations sequentially, the model was integrated from 2010 to 2040 with future SST and Sea Ice boundary data. This is the multi-model ensemble from four models of Coupled Model Intercomparison Project phase 5 (CMIP5) participating models based on the Representative Concentration Pathway scenario (RCP 8.5 and RCP 4.5) by IPCC AR5. The specification of models is summarized in Tab. 1. And we forced the change of CO_2 concentration and other greenhouse gases yearly from the Goddard Institute for Space Studies (GISS) National Aeronautics and Space Administration (NASA) for present-day climate simulation and the RCP database for future climate simulation.
For the validation of the present-day climate simulation, we used the various precipitation datasets. The first one is the monthly CMAP on a 2.5° lat/lon grid for 30 years (1979-2008). And the GPCP 1DD for 11 years from 1998 to 2008 was used. The third one is the daily TRMM 3B42 data and its

Tab. 1 - Specification of 4 models in CMIP5.
Tab. 1 - Specifiche di 4 modelli in CMIP5.

No	Model	Resolution	Institution	Country
1	CanESM2	2.8125°×2.8125°	CCCma	Canada
2	GISS-E2-R	2.5°×2°	NASA GISS	USA
3	HadGEM2-CC	1.875°×1.24°	MOHC	UK
4	HadGME2-ES	1.875°×1.24°		UK

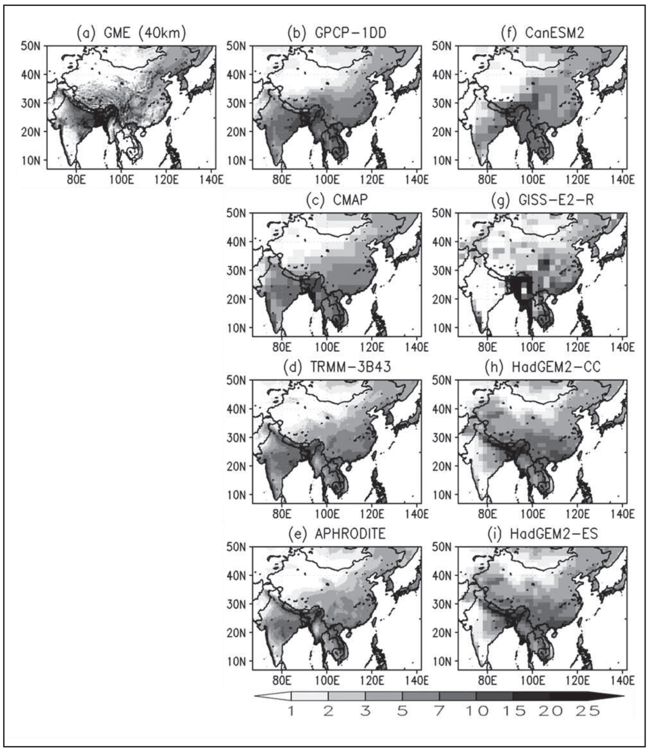

Fig. 1 - Spatial distribution of mean precipitation in JJA (1998-2008) over Asia region in (a) simulation, (b-e) observation and (f-i) CMIP5 models. Units are mm day^{-1}.
Fig. 1 - Distribuzione spaziale della precipitazione media in JJA (1998-2008) sulla regione Asia in (a) simulazione, (b-e) l'osservazione e (f-i) CMIP5 modelli. Le unità sono mm day-1.

horizontal resolution is 0.25° lat/lon for same years as the GPCP 1DD. The last one is the daily APHRODITE Version 1101 on the 0.25 degree over Monsoon Asia. This is the historical high-resolution daily precipitation based on rain gauge. Its period is 29 years from 1979 to 2007, but it exists only for land.

Results and Discussion

The geographical distributions of mean precipitation during JJA are shown in Fig. 1. The model reproduces the spatial mean precipitation well over Asia including the India, Bay of Bangal, Central China, Korea and Japan. Especially, the model reflects the orographical effect of precipitation as well as the better performance with relatively higher resolution in observations (TRMM 3B43 and APHRODITE data) than 4 CMIP5 models.
The spatial distribution of the changes in air 2m temperature and mean precipitation for JJA and DJF in near-future (2010-2040) is presented in Fig. 2 due to the global warming. In RCP 8.5 scenario, the projection by the GME model in 40-km resolution shows the increase of temperature over the North India, the West China and the Korean peninsula along the Asia Monsoon region during JJA. The model simulates the large increase of temperature during DJF over the India and West China region.

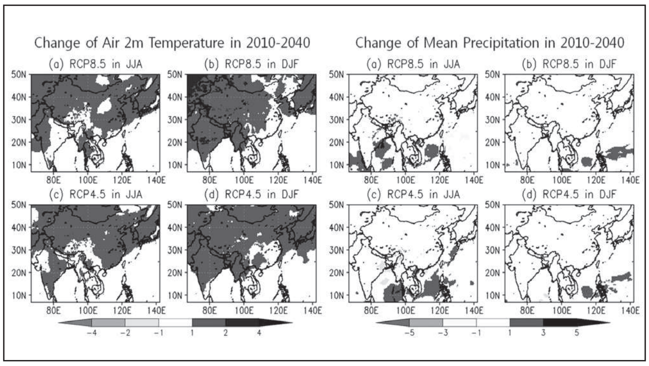

Fig. 2 - Seasonal change of air 2m temperature and mean precipitation for (a, c) JJA and (b, d) DJF in near-future (2010-2040) between two RCP scenarios. Units are K and mm day -1.
Fig. 2 - Variazione stagionale della temperatura dell'aria a 2m e precipitazioni medie per (a, c) JJA e (b, d) DJF nel prossimo futuro (2010-2040) tra due scenari di RCP. Unità sono K e giorno mm -1.

Differently from air 2m temperature the trend of precipitation does not show any organized development over Asia region in future. However, the high-resolution model simulates the significant decrease of precipitation during JJA over the Bay of Bengal. Of the two RCP scenarios, the RCP 4.5 is projected the more decrease than the RCP 8.5.

Conclusions

The high-resolution GCM was used for regional detail climate response for the future climate simulation due to the RCP scenario. In validation, it captures the detailed features in precipitation over the Asia region and the model matches relatively higher resolution observation data. In near-future during next 30 years, it shows the increase of air 2m temperature and precipitation over the Asia region.
Although the future climate projection by the AGCM is not able to capture accurately the response of regional climate change, the results may provide an essential data to estimate regionally detail temperature increase and changes in precipitation pattern over worldwide region.

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