Downscaling by Pseudo Global Warning Method

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1. Objectives

Climate change by increasing of greenhouse gas is usually estimated by General Circulation Model (GCM). However, horizontal resolution of the ordinary GCM is quite low, i.e., grid interval is about 100-300km, although these are being improving much with the computer power day by day. However, the resolution is still not enough to estimate the climate change in a basin, such as Seyhan river basin in Turkey. Downscaling of GCM using Regional Climate Model (RCM) may arrow to estimate climate and provides scenarios of the likely climate change in a basin, although GCMs and the methods of downscaling still have many problems for the reliable projection.

In generally, one of the largest difficulty in the downscale process using a nested regional climate model, is the bias of GCMs, especially shift of a regional scale climate system may gives serious error in the nested model (Wang et al, 2004). To avoid this difficulty, we present a new downscaling method called PGWM (Pseudo Global Warming Method) in which the boundary conditions are assumed to be a linear coupling of the reanalysis data (observation) and the difference component of the global warming estimated by GCMs. This assumption may valid when the change of the global warming is small enough and allows to neglect the nonlinear interaction between the climate change and the inter-annual variation of the regional climate systems.

2. Method

Figure 1 shows a flow chart of downscaling by PGWM. Reanalysis data are provided every 6 hours and are assumed as a boundary condition of the RCM. In the RCM, the reanalysis data are further interpolated for every time step when RCM simulates the current climate. This process reproduces the past climate using reanalysis data, which is called 'hindcast'. The hindcasted data are compared to in situ observation data and the results give feedback to the RCM in order to tune some parameters in the RCM. Two data sets of monthly climate are obtained by ten-years average of GCM produces. One is for the current climate during 1990s (period A) and another is for 2070s (period B). The difference of them is the climate change by the increase of greenhouse gases. Some of the 6 hourly reanalysis data and the different components, which are provided at each grid point and each month, are assumed to be as the boundary condition for the RCM in the future (PGWM run). The downscaled climate will be compare to the hindcast data.

A similar nesting method named 'anomaly nesting' has been presented by Vasubandhu and Kanamitsu 2004. Object of their method is to improve seasonal forecasts by regional climate models. They tested this method for a simulation of regional climate affected by some large scale climate systems such as ENSO or inter-annual variability around South America. A big difference from PGWM is that the boundary data are assumed to be the GCM products whose climate values have been replaced by the climate values estimated from the reanalysis data. Short term components, such as daily variation, are almost retain in GCM produces, while they will be replaced by these of reanalysis data in PGWM.

One of the advantage of PGWM is to allow to

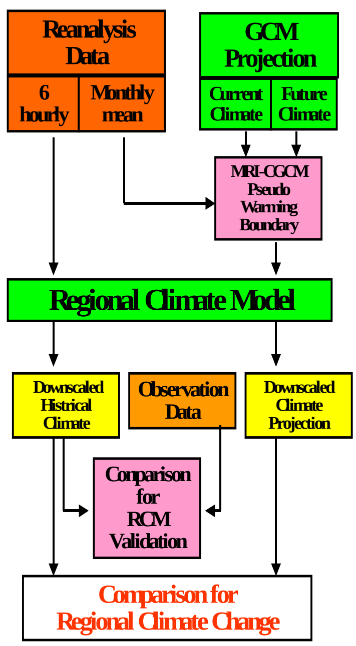

Fig.1. Flow chart of downscaling by pseudo global warming method (PGWM).

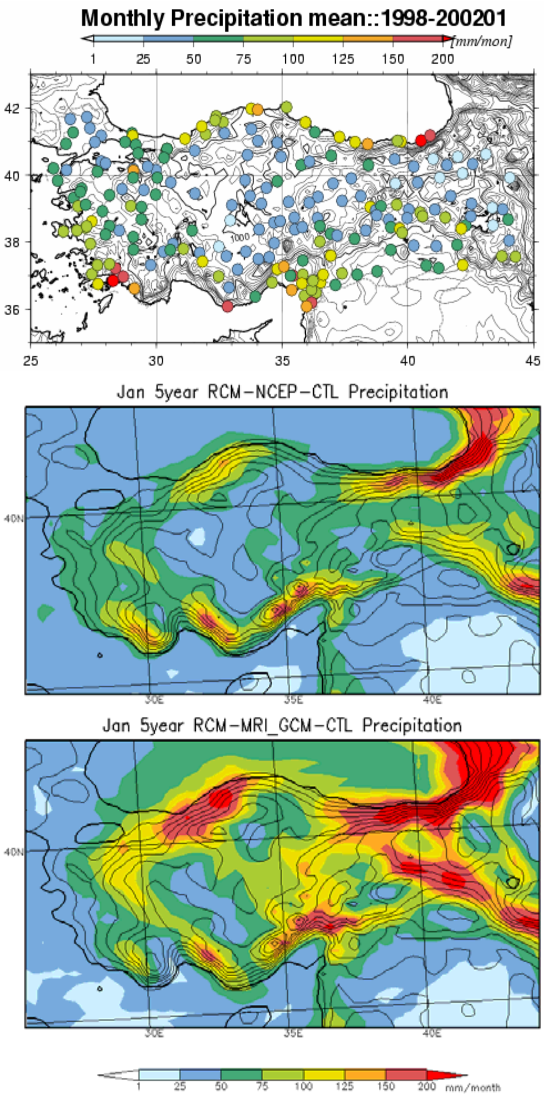

Fig. 2. Top panel:Monthly mean precipitation of in situ observation, January 1998-2002. Middle panel: Hindcasted precipitation in the same area and the same period as the top panel. Bottom: Simulated precipitation by the direct downscaling form the products of MRI-CGCM in the same period. Color bar is common for three panels.

estimate the global warming effects on the specific past year. This advantage makes easy to estimate climate difference between current and future climate without ensemble of numerous number of simulations. Usually the effects is only possible to estimate by the difference between the climatic mean of many years before and after global warming. Any GCM can not estimate the difference between each single year without large effects of natural inter-annual variation. When the difference of the global warming is smaller, detection of the global warming effect becomes more difficult because of inter-annual variation. This method have been already applied to Mongolia (Sato et al, 2006).

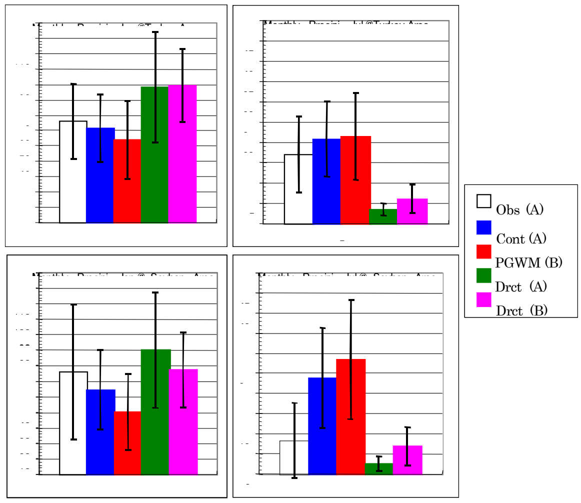

Fig. 3. .Projected monthly precipitation in January (left) and July (right) during the period A (1998-2002) and the period B (Five years in 2070s). Top panels indicate mean values in the entire Turkey and the bottom panels indicate those in the Seyhan basin. White bar indicates observed data in the period A, blue indicates the control run (hindcast in the period A), red indicates projection by PGWM (period B), green indicates the direct downscale from GCM (period A) and pink indicates the direct downscale in period B.

Comparison with direct down scaling

Downscaling by PGWM and ordinary direct downscaling are compared in order to discuss the accuracy and reliability of the method. Beside five years hindcast (control run) using NCEP/NCAR reanalysis data and five years projection during 2070s by PGWM, directly nesting runs driven by daily GCM products are also carried out for the periods A and B. Test periods are restricted to January and July. Global-scale projection data were provided by MRI-CGCM-2 (Yukimoto et al, 2001) assuming A2 scenario in Special Report on Emission Scenarios (SRES) (IPCC, 2000).

Figure 2 indicates monthly mean precipitation of in situ observation, January 1998-2002 (top panel), hindcasted precipitation in the same area and the same period (middle panel) and simulated precipitation during five years in 1990s by the direct downscaling form the products of MRI-CGCM (bottom). Color bar is common for three panels. We chose January and July for the test of PGWM, since amount of precipitation becomes large in winter and small in summer in this region. The hindcasted precipitation agree well to the observation, particularly heavy precipitation along the Black Sea and some areas along the Mediterranean. Horizontal distribution of the direct downscale also agree to the observation, but the amount is overestimated.

Projected total amount of precipitation in

January and July are shown in Figure 3 for the entire Turkey (top) and for the finest grid system around Seyhan basin (bottom). White bar indicates observed data in the period A, blue indicates the control run, namely; hindcast in the period A. Hindcast slightly overestimated in July but slightly underestimated in January. The red bars indicate projected precipitation during 2070s by PGWM (period B). The model projects that amount of precipitation will decrease in January but it slightly increase in July. Green bars and pink ones are five years mean precipitation by the direct downscaling from GCM in the period A and that in the period B, respectively. The direct downscaling overestimates and seriously underestimates during July.

Figure 4 indicate horizontal distribution of the difference in monthly precipitation between period A (1998-2002) and B (five years in 2070s) in January projected by PGWM (top) and by the direct downscaling (bottom). Dark blue indicate increasing in precipitation, while brown indicate decreasing. Precipitation change is depend on place in Turkey. The patterns of horizontal distribution have good similarity except for the Southeast corner of the Black Sea. Figure 5 is the same as Fig.4, but the finest grid system. The tendency is the same as Fig.4. These projections agree well each other, since the amplitude is somewhat larger in the direct simulation.

Figure 6 indicates the inter-annual variation of precipitation (top) and temperature (bottom). Inter-annual variation of the direct downscaling for the past year does not need to agree to observation, since only statistics of the variation has meaning. Temperature given by the direct downscaling from GCM-2 has strong cold bias. The hindcast (CTL) follows the inter-annual variation very well. Differences between the current years and the corresponding pseudo global warming year depend on years, but the amplitude of inter-annual variation of the difference is much smaller than those between a single year of period A and that of period B

3. Conclusions

PGWM not only reduces large scale model bias, it allows to estimate climate difference between current and future climate without ensemble of numerous number of simulations. This method has the certain advantages, but it needs further study to make sure the reliability for the extreme events.

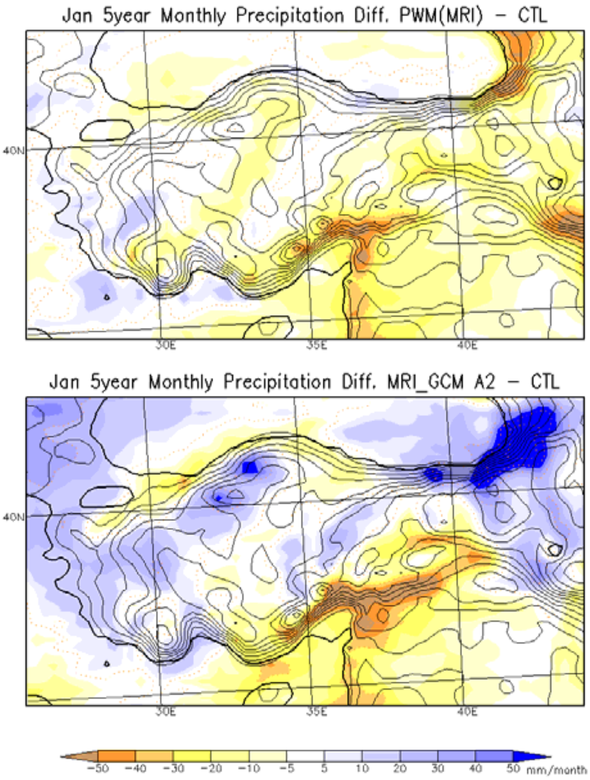

Fig.4. Difference in monthly precipitation between period A (1998-2002) and B (Five years in 2070s) in January. Top: projected by PGWM, Bottom: by the direct downscaling from GCM. Dark blue indicate increasing in precipitation, while brown indicate decreasing.

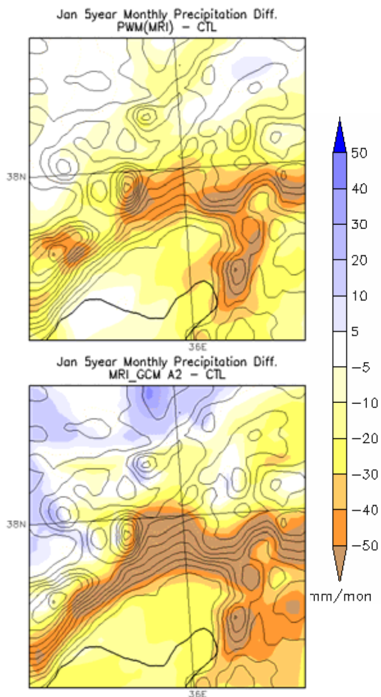

Fig. 5. Same as Fig.4, but for the finest grid system around Seyhan basin.

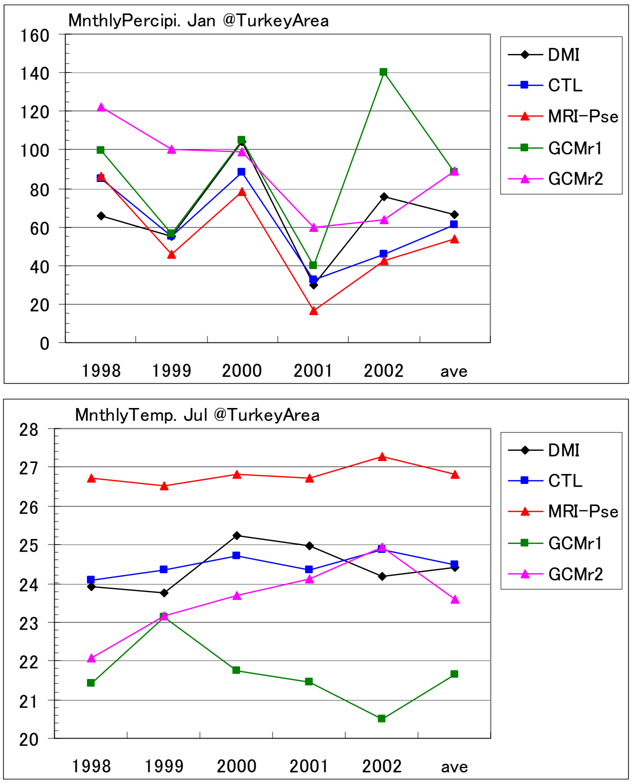

Fig. 6. Year to year variation of precipitation (top) and temperature (bottom). Meaning of color is same as Fig.3.

4. Reference

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