An assessment for downscaling methods for global warming in Turkey

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1. Objectives

Climate change by increasing of greenhouse gas is 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. 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 methods of downscaling still have many problems for the reliability of the prediction. In this report, the reliability of the prediction methods is discussed by the comparison between several methods.

We currently focused on the following five points: (1) providing a data set (2nd RUN) of the estimated hourly meteorological variables interpolated into the observation station points in the entire Turkey especially in Seyhan basin during 1990's and 2070's by the pseudo warming downscale method which has been developed in this project, (2) an assessment for the accuracy of the downscaling of temperature, insolation and precipitation in the Seyhan basin and reducing the model bias. The model bias must be as small as possible, since the estimation models for the effects of global warming, including crop models, hydrological models and so on, are quite sensitive to these data, (3)comparison between projections by the direct downscaling and the pseudo warming method in order to assess the reliability of the downscaling, (4)downscaling of another GCM products provided by CCSR/NIES, and (5)downscaling of current climate (hindcast) using ERA40, i.e., reanalysis data by ECMWF instead by NCEP/NCAR. The purpose of the last two are also assessments of the reliability of the downscaling

2. Meth0dorogy

Forcing data provided by GCMs

For the downscaling to Seyhan basin by RCM, the forcing data for the boundary condition of RCM are given by MRI-CGCM2 (Yukimoto et al., 2001; Kitoh et al., 2005) with T42 in wave truncation, which approximately corresponds to 2.5 degree horizontal resolution. Control run of MRI-CGCM2 simulates the current climate condition, while global warming run is performed based on A2 scenario in Special Report on Emission Scenarios (SRES) (IPCC, 2000). Meteorological data for both integrations are recorded in every six hours during 1991 to 2000 for the control run and 2071 to 2080 for the A2 scenario run. Beside MRI-CGCM2, products of the different CGCM which is provided by CCSR-NIES are also applied to the downscaling, in order to assess the model dependency in the Climate projection.

Simple downscaling by RCM

RCM-GCM run calculates Turkish climate with grid interval of 25km and 8.3km using products by MRI-CGCM2 whose grid interval is about 250km. RCM-GCM-CNTL run estimates regional climate in the period from 1997 to 2001. RCM-GCM-A2 run is carried out corresponding five years in 2070s using the products by MRI-CGCM2 SRES-A2 scenario run. The difference between RCM-GCM-A2 and RCM-GCM-CNTL is the component of the global warming during 1990s and 2070s. This method has been widely attempted to study regional impact of the global warming (e.g. Kato et al., 2001; Leung and Ghan, 1999). We have also tested the downscaling from the product of CGCM by CCSR-NIES after the SRES A2 scenario for only several months.

Pseudo worming ***(2nd RUN)***

Pseudo worming method is attempted to prevent bias in GCMs that is biggest concern to evaluate regional climate prediction. The NCEP/NCAR reanalysis data is used as a RCM forcing in RCM-NCEP-CNTL run for the period during 1994 to 2003, which is a hindcast experiment to demonstrate the ability of TERC-RAMS to reproduce the regional climate.

In RCM-NCEP-PWM run, new forcing dataset as mentioned below is prepared to simulate the regional climate influenced by the global warming. Monthly mean difference between control run (corresponding to 1990s) and A2 scenario run (corresponding to 2070s) is calculated for each 2.5 degree grid from GCM products (hereafter GWMD: Global Warming Monthly mean Difference), which indicates the change of spatial structure induced by the global warming.

The GWMD in wind speed, temperature, geopotential height specific humidity, and sea surface temperature are time-independently superimposed on each variable of six-hourly NCEP/NCAR reanalysis data as a perturbation from the current weather condition during 1990s. RCM-NCEP-PWM is expected to simulate cyclones and troughs with basically same structures during 1994 to 2003 except for that time-independent GWMD are added representing the perturbation induced by global warming in 2070s.

Generally, the precipitation difference caused by global warming is smaller than the bias of GCMs that is the difference in precipitation between observation and GCMs. The model bias should be reduced in RCM-NCEP-CNTL rather than in RCM-GCM-CNTL for the current regional climate simulation. Difference between RCM-GCM-CNTL and RCM-GCM-A2 gives the change of precipitation after global warming by method-G, which seems to be much smaller than the model bias, i.e., difference between observed precipitation and estimated one by RCM-GCM-CNTL. On the other hand, RCM-NCEP-PWM is expected to give more reasonable prediction than RCM-GCM-A2. A similar method was presented by Misra and Kanamitsu (2004) for the anomaly component insterd of global warming compoment.

High resolution GCM

High resolution GCM on the Earth Simulator (Kitoh,2005) presented Turkish climate simulated by MRI/JMS A-GCM TL959L60. The global model framework is designed to become a next generation numerical weather prediction model of the Japan Meteorological Agency in this resolution (global 20-km mesh). The Earth Simulator makes possible to run this huge numerical mode. 10-year control simulation was done with the climatological observed sea surface temperature (SST) corresponding to the 1982-1999 period (TL959-CNTL). Then, another 10-year global warming simulation (time-slice experiment) was performed by adding the SST anomalies derived from the MRI-CGCM T42L30 assuming SRES A1B (TL959-A1B) scenario experiment corresponding to the end of the 21st century (2081-2100 mean). The scenario is different from the downscaling and the averaging period is also different (3 month mean), comparing with results are useful for evaluate the reliability.

3. Results

Comparison with observed precipitation

Figure1(top) indicates monthly precipi- tation during January in five years of 1997-2001 and simulated (hindcasted) five years precipitation (bottom) for January. Precipitation pattern can be simulated quite well. However, horizontal distribution of precipitation in Seyhan basin shows some discrepancy between observation and simulation (Fig.2 left and right). Model overestimates precipitation in the mountainous regions but under estimates in the plain. This means that the downscaling with very small grid interval to the basin scale still has some difficulty.

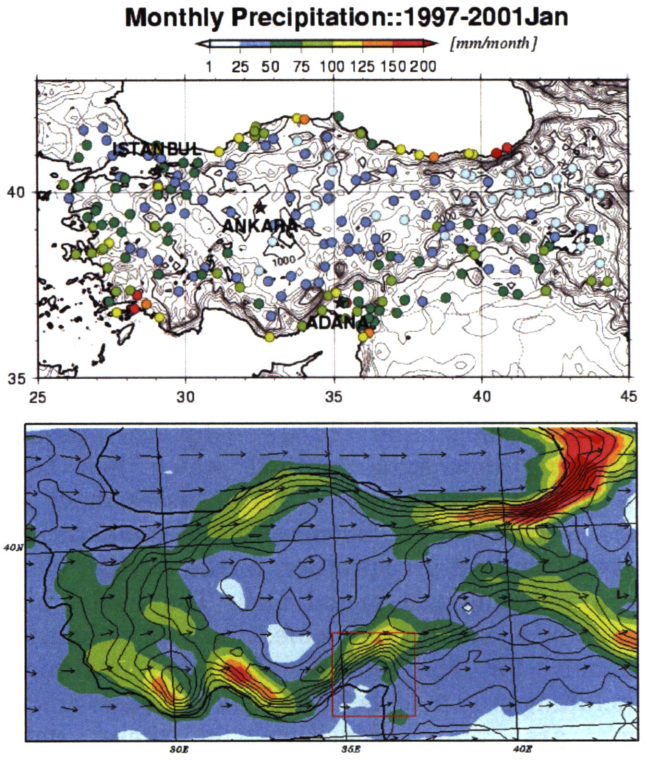
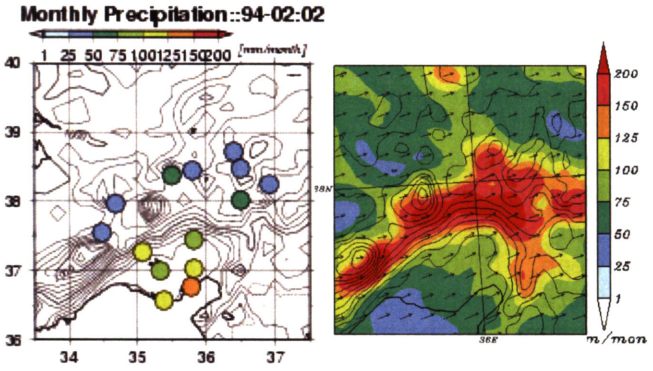


Figure 1:Monthly precipitation during January in five years of 1997-2001.Top panel: observation, Bottom panel: Simulation (hindcast)

Figure2:Horizontal distribution of precipitation in Seyhan basin, Left: observation, Right: Simulation.



Comparison with observed temperature

Mean temperature at ADANA, KONYA and SINOP estimated by RCM-NCEP-CNTL agrees well to the observation, while it has cold bias, especially at ADANA in January. Temperature by RCM-GCM-CNTL has almost always cold bias. Temperature change between 1990s and 2070s is predicted to increase by about 2 to 3 degree in these stations by both RCM-NCEP-PWM and RCM-GCM-A2.

The 2nd RUN mentioned above has cold bias. We are now adjusting model parameters to decrease the bias. Initial guess value of soil moisture before assimilation, radiation parameters for the sub-grid cloud amount, exchange coefficient for heat and moisture over the ocean are modified using observed radiation data. Figure 4 shows daily mean temperature during 2000. Estimated temperature agree well during winter, spring and summer, although some cold bias still remain during fall

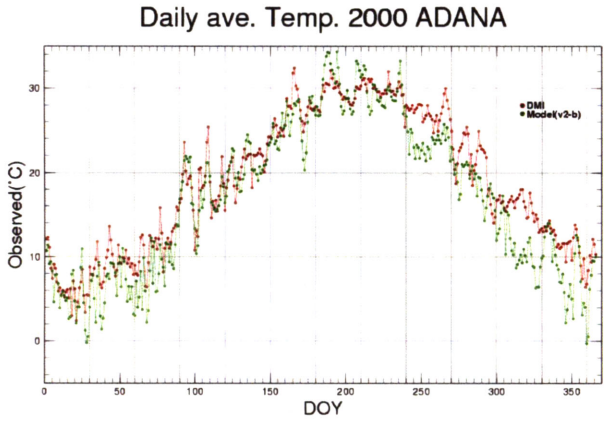


Figure 3: Daily mean temperature at Adana 2000. Red: Observation, Green: modified 2nd Run with the turned parameters.

Comparison between two downscaling methods

Estimated precipitation patterns in the current years agree better in the order of RCM-NCEP-CNTL, TL959-CNTL and RCM-GCM-CNTL. The accuracy of current simulation almost does not depend on the reanalysis data, NCEP/NCAR or ERA40. The difference in precipitation between 1990s and 2070s depends on the models. In the most months, precipitation estimated to be decrease, but TL959 predict increase in precipitation in spring and autumn as well as RCM-GCM-CNTL in January.

Top panel in Figure 4 indicates precipitation change between 1990's and 2070's estimated by the direct downscaling, while the bottom panel shows that estimated by the pseudo downscaling. The pseudo downscaling predicts decreasing in precipitation more clearly. Spatial pattern of precipitation change has a clear similarity.

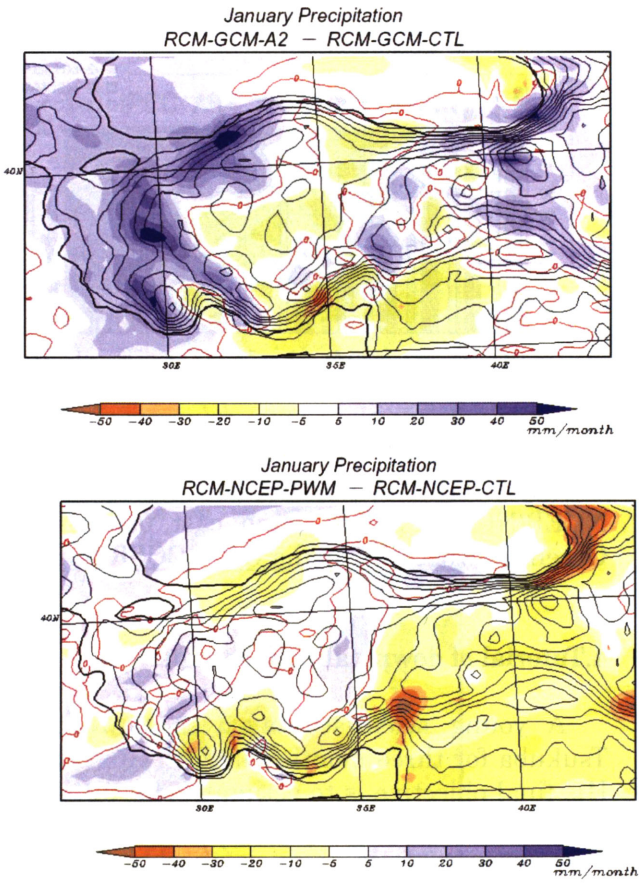


Figure 4: Precipitation change between 1990's and 2070's. Blue: increase. Top: Direct downscaling, Bottom: Pseudo Downscaling.

Downscaling from CCSR/NIES GCM

Figure 5 and 6 shows monthly precipitation in January 2000 and its seasonal variation obtained by the directly downscaled from GCM by CCSR/NIES with observation and hindcasts using NCEP/NCAR. The downscaling from CCSR/NIES overestimates precipitation in July, while downscaling from MRI-GCM underestimated.

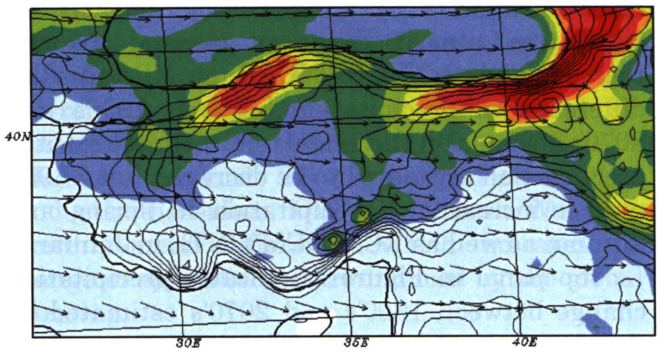


Figure 5: Monthly precipitation in January 2000 directly downscaled from GCM by CCSR/NIES. Color means amount of precipitation as same as Fig.1.

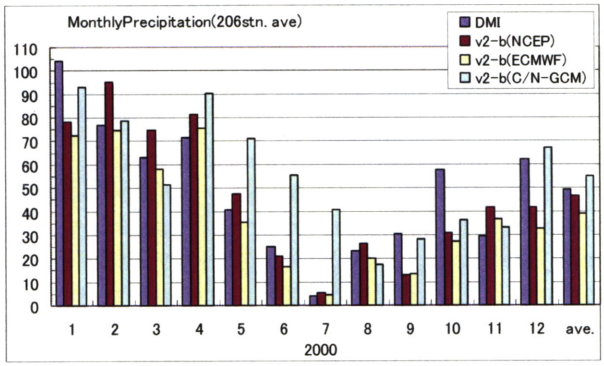


Figure 6: Monthly precipitation in 2000 in entire Turkey. Blue: Observation, Red: Hind cast using NCEP/NCAR, Yellow: Hind cast using ERA40, Green: Downscaling using GCM CCSR/NIES.

4.Tutorial of downscaling technique

A young scientist stayed in University of Tsukuba for three months till 26th August 2005.. His final objective is to estimate The Influence of Climate Change on Crop Production in Turkey. The purpose of this stay is to obtain scientific knowledge and practical technology for the downscaling of global warming. He finished the lectures on the outline regional climate model and mastered the operation of RCM in a PC and downscaling method by RCM. He also obtained reanalysis data and other data which are necessary to run the model for the downscale of climate change into the area around Seyhan river basin in Turkey.

5.Conclusions

RCM-NCEP-CNTL simulate most accurately current climate in Turkey for precipitation and also temperature. This is quite reasonable because of using observational boundary forcing. Precipitation change between 1990s and 2070s are predicted to have decreasing tendency. However, the tendency strongly depends on the methods and it implies that the reliability is not high.

On the other hand, both of the predictions by RCM-NCEP-PWM and RCM-GCM-A2 are quite similar each other for temperature change between 1990s and 2070s, although the temperate along the coastline has stronger dependency on the method. The reliability for the temperature change is higher than that for precipitation, while it may have larger bias along the coastline. We cannot say yet that the reliability of prediction for the difference between current climate and the future climate is very high for the both method of simple downscaling and pseudo warming. However, the method of Pseudo warming (RCM-NCEP-PWM) may more useful to apply to the quantitative estimation of the effects of climate change to agriculture, because of better estimation for the current climate (RCM-NCEP-CNTL).

Reference

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