Journal of
Earth Science & Climatic Change

Hassan et al., J Earth Sci Clim Change 2014, 5:7
DOI: 10.4172/2157-7617.1000214

Research Article Open Access

Temperature and Precipitation Climatology Assessment over South Asia using the Regional Climate Model (RegCM4.3): An Evaluation of the Model Performance

Mujtaba Hassan[1,2*], Du Penfei[1], Waheed Iqbal[3], Wang Can[1], Fang Wei[1] and Wulong Ba[1]

[1]*State Key Laboratory of Environmental Simulation and Pollution Control (SKLESPC), School of Environment, Tsinghua University Beijing, China*

[2]*Department of Space Science, Institute of Space Technology, Islamabad 44000, Pakistan*

[3]*Research and Development Division, Pakistan Meteorological Department, Islamabad 44000, Pakistan*

[*]**Corresponding author:** Mujtaba Hassan, State Key Laboratory of Environmental Simulation and Pollution Control (SKLESPC), School of Environment, Tsinghua University Beijing, China, Tel: +86-131200765; E-mail: mhassan512@yahoo.com

Rec date: Jun 20, 2014, **Acc date:** Aug 20, 2014, **Pub date:** Aug 30, 2014

Abstract

Climate modeling is a significant tool to reproduce the observed features of present climate changes and can provide reliable estimations for future climate changes at global and regional levels. In the present study we use latest version of International Center for Theoretical Physics (ICTP) regional climate model (RegCM4.3) to examine its ability by analyzing the European Community-Hamburg atmospheric model (ECHAM5) and the European Centre for Medium-Range Weather Forecast (ECMWF) 40 years reanalysis data (ERA-40) over South Asia. Seasonal mean climatology and annual cycle are compared with different observation based data sets and also with the reanalysis and driving GCM. Two experiments are conducted for present day simulation (1971-2000) by using ERA-40 reanalysis and ECHAM5 GCM to provide the initial and lateral boundary conditions. In spite of complex topography of the domain RegCM4.3 shows an improved performance in various aspects as compared to the earlier applications of this model over South Asia. Near surface air temperature are reproduced well over the most part of the domain. Indian monsoon precipitation patterns are better captured by RegCM4.3 as compared to the driving data set of ECHAM5 and ERA40. Simulation results show that RegCM4.3 has cold bias in winter and summer over the foothills of the Hindu-Kush-Himalaya (HKH) region. Simulation with ERA40 and ECHAM5 overestimated the seasonal mean precipitation over some part of the domain which requires further improvement in the physical parameterization scheme of RegCM4.3.

Keywords: Regional climate model; Seasonal mean precipitation; Physical parameterization

Introduction

Atmospheric Global Circulation Model (AGCM) and Atmospheric-Ocean Global Circulation Model (AOGCM) do not resolve the topography, land use and clouds features at regional scales because of their coarse resolution. A number of regional climate models (RCMs) have been developed to study the regional climate processes, regional climate change impacts and seasonal climate variability. Downscaling techniques are commonly used to address the scale differences between the coarse resolution global climate model (GCM) output and the RCM at local catchment scales for climate change impact assessments [1].

In dynamic downscaling, high resolution information can be derived using RCM for a particular domain by employing GCM and reanalysis data at the lateral boundaries [2]. South Asia has diverse climate and characterize by complex topographical features and marked extensive mountain ranges of HKH. Precipitation and temperature regimes of the region are complex due to different weather systems that prevail during the whole year and pose a great challenge to the regional climate models in reproducing the observed climatology [3,4].

Various studies have been conducted during the last decade in order to investigate the performance of different RCMs over South Asia. Syed et al. [4] found the uncertainties in the south Asian summer monsoon using RegCM4 and PRECIS RCMs after downscaling from same global dataset and concluded that the biases appear to come from the difference in the RCM Physics. Islam et al. [5] investigated the frequency of cold and warm spells duration over Pakistan using PRECIS regional climate model. Dash et al. [6] successfully simulated some important characteristics of the Indian summer monsoon circulation using RegCM3. Lucas-Picher et al. [7] used four RCMs (CLM, HadRM3, HIRHAM5, and REMO) to verify their ability to represent the Indian monsoon characteristics for the period 1981–2000, using lateral boundary conditions from ERA-40. Ashfaq et al. [8] applied RegCM3 over South Asia and found the changes in the monsoon dynamic that could have vital effects on decreasing summer precipitation over some part of South Asia. Saeed et al. [9] performed the simulation at 50 km horizontal resolution using REMO RCM driven by ERA40 reanalysis at its lateral boundaries over South Asia. REMO RCM captured the monsoon onset and the movement of Inter Tropical Convergence Zone (ITCZ) reasonably well during the boreal summer. These studies are very important and provide a good basis for the climate change studies using the RCMs, however the objective of each study was different. Some studies focused on climate change and extreme events while other on the uncertainties of the RCMs. The improvements in the newer version of the RCM RegCM need through evaluation, which is not covered in the previous studies.

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The purpose of the present study is to investigate the ability of ICTP latest version of regional climate model RegCM4.3 to simulate the present day climatology at 50 km horizontal resolution over South Asia between 50-100°E and 5-50°N. The ability of the RegCM4.3 is analyzed in a way that the result will help us to further use the output of the RCM for climate change impact assessment especially on water resources.

Material and Methods

Model description

ICTP regional climate model version RegCM4.3 is adopted in the present study. The first version of RegCM (RegCM1) developed in 1980s [10,11] evolved to later versions (RegCM2 & RegCM2.5) in the early 1990s [2,12] with upgrades described by Pal et al. [13] in 2000s. RegCM the first limited area model that has wide range of applications from process studies to paleo-climate and future climate projections [14]. RegCM3 underwent significant evolution in terms of software code and Physics which led to release of its fourth version. RegCM4.3 is a primitive equation model and it is, compressible with sigma-p vertical coordinate running on an Arakawa B-grid in which wind and thermo dynamical variables are horizontally staggered. The dynamic structure of RegCM4.3 is same as that of hydrostatic version of the meso scale model version 5 (MM5) of the National Center for Atmospheric Research (NCAR) and Pennsylvania State University [15].

For land surface process representation RegCM4.3 include two schemes, the first one is Biosphere Atmosphere Transfer Scheme (BATS) of Dickinson et al. [16] which include twenty (20) surface types and twelve (12) soil color and soil texture types. The second scheme option for land surface process representation is Community Land Model version CLM3.5 which is the major addition in RegCM4.3 [17]. RegCM4.3 includes radiation package of NCAR's global community climate model version CCM3 [18] for radiative transfer calculation. CCM3 include all greenhouse gases and delta-Eddington formulation used to calculate the solar radiative processes [19]. Resolved scale precipitation scheme is based on the sub grid explicit moisture (SUBEX) parameterization of Pal et al. [20] that includes prognostic equation for cloud water. RegCM4.3 uses Holtslag et al. [21] scheme based on non-local diffusion concept for the representation of Planetary Boundary Layer (PBL) processes. This current scheme underwent various modifications and a new PBL scheme of University of Washington was implemented in the current version of the model [22,23]. Three cumulus convective schemes are available in the current version of RegCM4.3. The first one is Kuo-type scheme of Athens (1997) that has been available since the first version release of RegCM1. This scheme is activated when the column moisture convergence exceeds a threshold value. This scheme provides poor precipitation simulation as compared to the other available convective schemes. Grell [15] cumulus convective scheme used in RegCM4.3 is the simplification of the Arakawa and Schubert parameterization. In this scheme clouds are considered as two steady state circulations including an updraft and penetrative downdraft. Grell scheme is triggered when a parcel reaches the moist convection level. Grell scheme includes two closure assumptions: an Arakawa-Schubert in which buoyant energy is immediately released at each time step and Fritsch-Chappell type in which all available buoyant energy (CAPE) dissipates at a specified time step of 30 min [14]. Third cumulus scheme available in RegCM4.3 is MIT Emanuel [24,25] in which convection is triggered when buoyancy level is higher than the cloud base. This scheme tends to produce extensive precipitation over land and after activation of the MIT scheme it is difficult to decelerate it. MIT include number parameters that can be used over the different climate regions and this scheme is considered as most complex of the other three.

Data and experimental design

Before applying the RCM for future climate changes it is important to check the accuracy of the model over a particular region to successfully reproduce the observed regional climate characteristics. Therefore we tested RegCM4.3 with two experiments over South Asia. In the first experiment European Center for Medium Range Weather Forecast (ECMWF) 40 years reanalysis (ERA40) data with a grid spacing of 2.5°×2.5° dynamically downscaled to 50x50 km horizontal resolution using RegCM4.3. The second experiment performed using RegCM4.3 with lateral boundary condition forced from the fifth generation of European Community Hamburg atmospheric general circulation model ECHAM5 [26] developed by Max Plank Institute for Meteorology Germany. Both experiments are conducted for Reference Run (RF) which is 30 years period from 1970-2000 and named as RegCM4.3-ERA40 and RegCM4.3-ECHAM5 respectively. First year was considered as the spin up period and hence excluded from the analysis. Sea surface temperature data obtained from Global Ice Coverage and Sea Surface Temperature (GISST) with a resolution of 1×1 degree [27]. United State Geological Survey (USGS) and Global Land Cover Characteristics data sets at 10 min resolution used for model topography and land use (GLCC) [28]. For the validation of present day climate over South Asia, the output of RegCM4.3 is compared against ERA40 and ECHAM5 GCM along with the observed data set of Climate Research Unit (CRU) and University of Delaware (UDEL). The CRU data set is developed by University of East Angelina [29] which is available from 1901 to 2012.

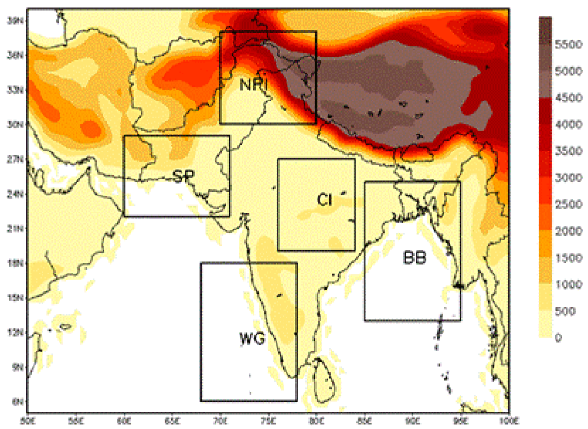

Figure 1: Domain of the RegCM4.3 for South Asia. The boxes represent the selected regions

UDEL Global surface air temperature and precipitation data set is developed by University of Delaware which is available from 1900 to 2008 [30]. The domain is shown in Figure 1 which is further divided into five sub regions i.e Western Ghats (WG), Central India (CI), Bay of Bengal (BB), Northern Pakistan and India (NPI) and Southern

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Pakistan (SP) in order to broadly represent the different Asian climatic regions. In the present study we evaluate the performance of RegCM4.3 for seasonal mean climatology and annual cycle from 1971-2000 with a horizontal resolution of 50 km over South Asia.

Results

Seasonal mean climatology

In order to evaluate the performance of RegCM4.3 we provide here the seasonal variability of climate for temperature and precipitation by considering two climatological seasons, i.e. DJF (December, January and February) and JJA (June, July and August). These two seasons have the weather system that contributed to major amount of precipitation over the whole region with much contribution in JJA.

Temperature climatology for winter season (DJF)

Figure 2a-f shows the seasonal surface air temperature of winter season (DJF) for observations (CRU and UDEL), driving data (ERA40 and ECHAM5) and two RegCM4.3 simulations forced by ERA40 and ECHAM5 for the period of 1971-2000. Temperature biases with respect to CRU and temperature differences for winter season between two observations, two driving data and CRU, ECHAM5 and ERA40 and between two simulations are displayed in Figure 3a-h.

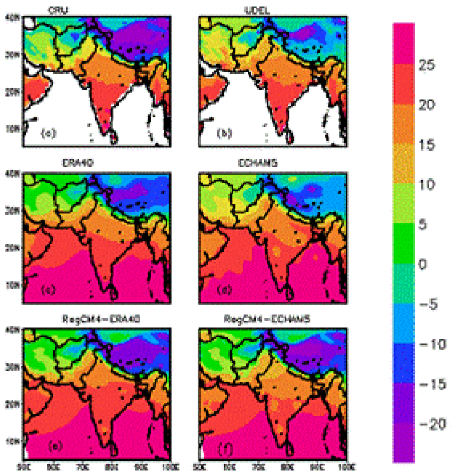

Figure 2: Averaged (1971-2000) two meter air temperature (°C) in DJF for (a) CRU, (b) UDEL, (c) ERA40, (d) ECHAM5, (e) RegCM4.3-ERA40, (f) RegCM4.3-ECHAM5

Both observational data sets show the similar spatial pattern for 2 m air temperature over the most part of the domain. However UDEL remained warmer over the NPI as compared to CRU and warm bias up to 4°C is recorded over the northern area of Pakistan. The two boundary forcing data sets also exhibited similar spatial characteristics of surface temperature. ERA40 reanalysis recorded cooler comparative to ECHAM5 GCM over NPI and cold bias up to -4°C observed particularly over CI and WG of the domain. The behavior of RegCM4.3-ERA40 and RegCM4.3-ECHAM5 in simulating the surface temperature is very similar. The biases are considerably reduced after down scaling two global data set with RegCM4.3. In winter season RegCM4.3-ERA40 output with respect to CRU show warm temperature between 2 to 4°C over the Central India. On the other hand RegCM4.3-ECHAM5 exhibit colder conditions over the HKH and NPI regions. The maximum seasonal mean temperature for winter season (DJF) is recorded around 25°C over WG and -20°C minimum over NPI. Winter temperatures for the rest of the regions (SP, BB and CI) remained between -10 to 20°C.

Temperature climatology for summer season (JJA)

The 2 m air temperature and respective biases between the observed as well as derived and simulated data set are shown in Figure 4 and 5. There are significant difference between the CRU and UDEL data set in the mean temperature (Figure 4a and 4b). CRU is warmer over the central Pakistan and Tibetan Plateau.

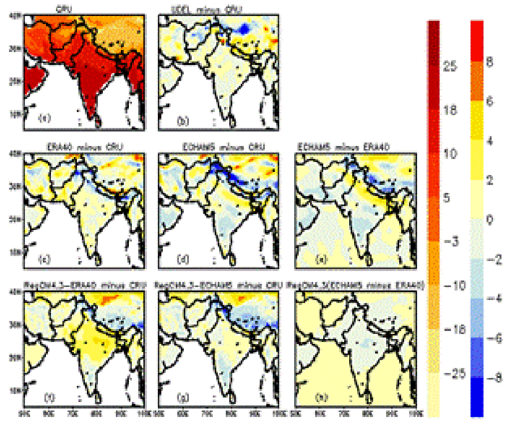

Figure 3: Spatial distribution of temperature bias (°C) for winter season (DJF) (a) CRU, (b) UDEL minus CRU, (c) ERA40 minus CRU, (d) ECHAM5 minus CRU, (e) ECHAM5 minus ERA40, (f) RegCM4.3-ERA40 minus CRU, (g) RegCM4.3-ECHAM5 minus CRU, (h) RegCM4.3 (ECHAM5 minus ERA40)

Large differences between ERA40 reanalysis and ECHAM5 GCM are seen over some part of the domain. ECHAM5 produced 4 to 8°C warmer climatology in the CI and NPI. A cold bias of -2 to -4°C is also seen in ECHAM5 over Southern part of the domain as compared to CRU (Figure 5d). However this bias is reduced to -1°C after downscaling ECHAM5 with RegCM4.3 and the differences between RegCM4.3-ECHAM5 and CRU are very small (Figure 5g). ECHAM5-forced RegCM4.3 and ERA40-forced RegCM4.3 output of near surface air temperature are similar to that of observations for summer season except over some part of the domain where temperature are overestimated. Cold bias of -2 to -5°C and warm bias of 2 to 5°C between RegCM4.3-ERA40 and CRU observed along the foothills of HKH and Central India and Pakistan regions respectively (Figure 5f). The warm bias is considerably small in case of RegCM4.3-ECHAM5 (Figure 5g). Maximum summer temperature recorded up to 35°C in the Central Indian sub-continent and minimum temperature around 20°C occurred in CIP region.

In general RegCM4.3 had a cold bias in winter over northern part of the domain when downscaled with both ERA40 and ECHAM5 boundary forcing data sets. This cold bias is strong in summer and reached up to -8°C. Warm winter bias of RegCM4.3-ERA40 with respect to CRU also exists in the central part of the domain. On the

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other hand RegCM4.3 has a stronger warm summer bias over the Central India and Pakistan as compared to the warm winter bias.

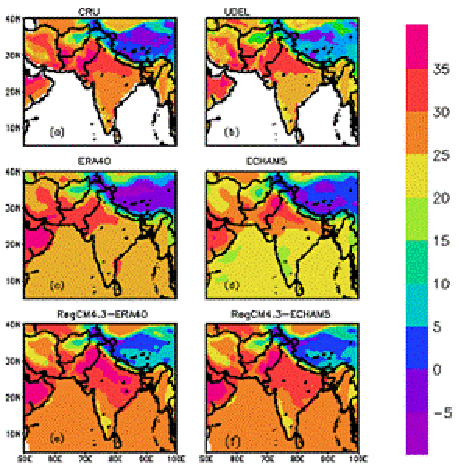

Figure 4: Averaged (1971-2000) two meter air temperature (°C) in JJA for (a) CRU, (b) UDEL, (c) ERA40, (d) ECHAM5, (e) RegCM4.3-ERA40, (f) RegCM4.3-ECHAM5

These biases seem to come from the driving data set as well as from the Physics of the model. RegCM has some systematic biases over this region as reported by Gao et al. [4,31].

Precipitation climatology for winter season (DJF)

Winter precipitation over South Asia is mostly associated with the eastward propagating westerly's which are originating from the Mediterranean. In this section the spatial pattern of the winter precipitation (DJF) are examined. In Figure 6a-f mean seasonal precipitation climatology is presented with CRU, UDEL, ERA40, ECHAM5, RegCM4.3 ERA40 and RegCM4.3-ECHAM5 data set. Whereas the comparison of seasonal mean precipitation for winter season of RegCM4.3 which is forced with ECHAM5 and ERA40 with respect to observational data set of CRU, UDEL and deriving global data set for the period of 1971-2000 are given in Figure 7a-h.

Regional climate model RegCM4.3 forced with global data set overestimated the spatial pattern of winter precipitation over the most part of the domain. CRU and UDEL show almost similar values and spatial pattern of DJF seasonal mean precipitation (Figure 6a and 6b).

The difference between CRU and UDEL is only 1 mm/day in the northern Pakistan and India. ERA40 is drier and poorly simulated the winter precipitation over the South Asia domain. A dry winter bias of 2 mm/day between ERA40 and CRU is observed over the Northern Pakistan (Figure 7c). ECHAM5 global model is wetter over the NPI regions and the differences between ECHAM5 and UDEL are very small. The maximum precipitation occurred over the NPI region up to 5 mm/day and minimum winter mean precipitation is observed below 2 mm/day. Wet bias between 2-4 mm/day is seen over the north east India (Figure 7d). Averaged winter precipitation from 1971-2000 for RegCM4.3 simulated with ERA40 and ECHAM5 is above 5 mm/day over northern Pakistan and adjoining areas of south India peninsular. RegCM4.3-ERA40 and RegCM4.3-ECHAM5 generates the maximum intensity of winter precipitation over the mountain areas of HKH and the adjoining areas of WG. The spatial distribution of wet winter bias is similar in both simulations.

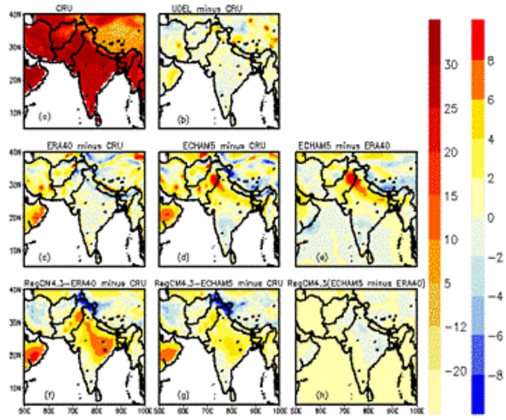

Figure 5: Spatial distribution of temperature bias (°C) for summer season (JJA) (a) CRU, (b) UDEL minus CRU, (c) ERA40 minus CRU, (d) ECHAM5 minus CRU, (e) ECHAM5 minus ERA40, (f) RegCM4.3-ERA40 minus CRU, (g) RegCM4.3-ECHAM5 minus CRU, (h) RegCM4.3 (ECHAM5 minus ERA40)

Although RegCM RCM reproduce the regional precipitation pattern well but also tend to show the wet bias over some parts of the domain. Figure 7f and 7g depict the winter wet bias up to 4 mm/day over the HKH as simulated by RegCM4.3 with ERA40 and ECHAM5 forcing dataset. The cumulus convective scheme used in the present study is MIT Emannuel [24] which trigged when buoyancy is higher than the cloud base level. Emannuel scheme tend to produce excessive precipitation over land as compare to other schemes (Grell and Kuo). As soon as the MIT scheme activated particularly in the presence of an individual precipitation event it become very difficult to decelerate it [14].

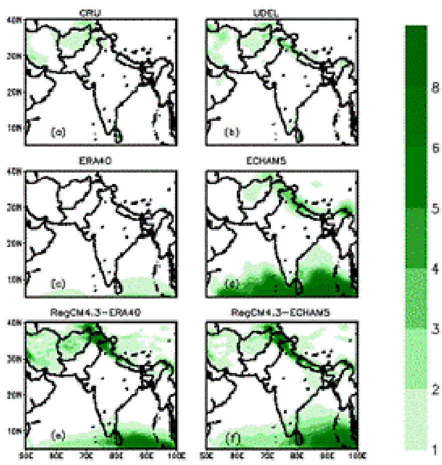

Figure 6: DJF average (1971-2000) precipitation (in mm/day) for (a) CRU, (b) UDEL, (c) ERA40, (d) ECHAM5, (e) RegCM4.3-ERA40, (f) RegCM4.3-ECHAM5

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We note that systematic bias depends on the choice of parameterization schemes and different schemes have different performance over different regions. For example Ozturk et al. [32], Dash et al. [6] and Syed et al. [4] used Grell scheme while simulating the major characteristics of South Asia precipitation using RegCM RCM. Their results showed that Grell scheme tends to produce the weak seasonal mean precipitation.

Precipitation climatology for summer season (JJA)

June, July and August is the South Asian summer monsoon season during which surface wind is northeasterly direction over the major parts of Arabian Sea and BB. Figure 8a-f present the summer monsoon precipitation climatology for observations (CRU and UDEL), driving data (ERA40 and ECHAM5) and two RegCM4.3 simulations for the period of 1971-2000. Figure 9a and 9h) show the respective biases in summer monsoon season with respective to CRU, along with the difference between the two boundary forcing data set and between the two simulations with RegCM4.3. The observational data set of CRU exhibit excessive precipitation over the complex terrain along the adjoining areas of Central India, Nepal, Bangladesh and Bhutan. The precipitation intensity decreases as monsoon penetrated into the NPI along the foothills of HKH.

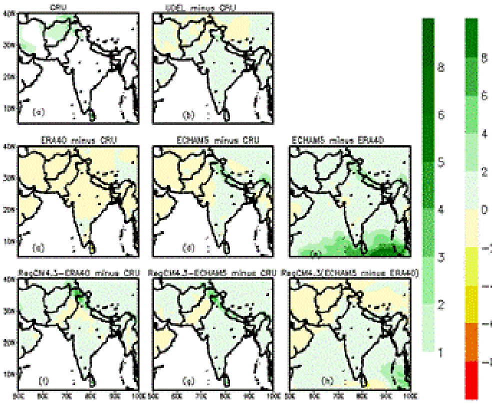

Figure 7: Biases in mean (1971-2000) precipitation (mm/day) for winter season (DJF) (a) CRU, (b) UDEL minus CRU, (c) ERA40 minus CRU, (d) ECHAM5 minus CRU, (e) ECHAM5 minus ERA40, (f) RegCM4.3-ERA40 minus CRU, (g) RegCM4.3-ECHAM5 minus CRU, (h) RegCM4.3 (ECHAM5 minus ERA40)

Maximum precipitation intensity as observed from CRU is up to 12 mm/day. The mean precipitation over NPI is below 6 mm/day. There is no considerable differences noted between CRU and UDEL and both observations exhibit similar spatial characteristics of South Asian summer monsoon precipitation. ERA40 is drier as compared to ECHAM5 and again poorly simulated the seasonal mean precipitation over the most part of the domain. ECHAM5 GCM is wetter and overestimated the seasonal mean precipitation as compared to CRU and the maximum precipitation is above 12 mm/day (Figure 8d). A dry bias reached up to -8 mm/day in the case of ERA40 minus CRU (Figure 9c). RegCM4.3 forced with ERA40 and ECHAM5 global data sets reproduced the summer monsoon precipitation reasonably well as compared to respective driving field. RegCM4.3-ERA40 and RegCM4.3-ECHAM5 seasonal mean climatology appeared to be very close to the CRU and UDEL observations. Both simulations captured the maximum precipitation over Nepal, Bhutan and Bangladesh and along the adjoining areas of WG and BB. The mean precipitation reached up to 12 mm/day over Nepal, Bhutan and Bangladesh. The South Asian summer monsoon is not well penetrated into Northern Pakistan and most of NPI regions remain drier. Extensive differences can be seen between the forcing field and simulation (Figure 9c-g). ECHAM5 has a wet bias over most part of the domain and the maximum bias of 6 mm/day seen over Nepal (Figure 9d). Although in general both simulations have same behavior, the amount of precipitation in RegCM4.3-ECHAM5 is more as compared to RegCM4.3-ERA40 particularly over the BB and WG.

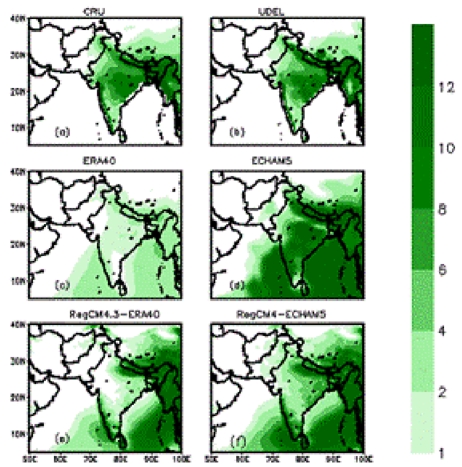

Figure 8: JJA average (1971-2000) precipitation (in mm/day) for (a) CRU, (b) UDEL, (c) ERA40, (d) ECHAM5, (e) RegCM4.3-ERA40, (f) RegCM4.3-ECHAM5

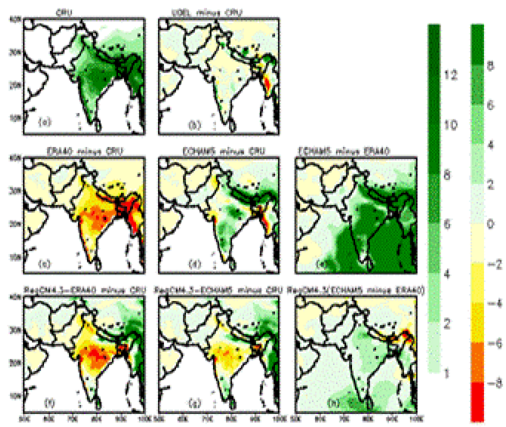

Figure 9: Biases in mean (1971-2000) precipitation (mm/day) for summer season (JJA) (a) CRU, (b) UDEL minus CRU, (c) ERA40 minus CRU, (d) ECHAM5 minus CRU, (e) ECHAM5 minus ERA40, (f) RegCM4.3-ERA40 minus CRU, (g) RegCM4.3-ECHAM5 minus CRU, (h) RegCM4.3 (ECHAM5 minus ERA40)

RegCM4.3-ERA40 underestimated the mean precipitation over the central India and dry bias up to -8 mm/day can be seen that appeared to come from the driving field (Figure 9f). However this dry bias is less

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as compared to the ERA40 reanalysis data set. The wet bias of 2 to 6 mm/day observed over Myanmar and Bangladesh in the case of RegCM4.3 simulation with ERA40 reanalysis. RegCM4.3-ECHAM5 is wetter as compared to RegCM4.3-ERA40 and dry bias less than -5 mm/day seen over Central India (Figure 9g and 9h). It is to be noted that the regional biases are smaller in both simulations compared to two driving fields. Previous studies have shown that the simulation of South Asian summer monsoon precipitation by RegCM is sensitive to the physics parameterization used. Kar et al. [33] and Acharya et al. [34] also found that RCM has some systematic biases while simulating the summer monsoon precipitation over this region. As described in section 2.1.3, RegCM4.3 simulated excessive precipitation with the MIT convective scheme. These biases again seem to come from the physics of the model as well as inherited from the driving field. However in both simulation RegCM4.3 reduces the temperature and precipitation biases and improve the simulation result with respect to the driving field. Gao et al. [35], Giorgi and Mearns [2], Brakovic and Gregory [36] and Rauscher et al. [37] also reported improvement in RCM over their respective regions.

Mean annual cycle

The mean annual cycle of RegCM4.3 simulated temperature (°C) and precipitation (mm/day) is calculated in this section over NPI, BB and WG sub region of South Asia. Figure 10 display the area averaged values of annual cycle of temperature over each sub region for CRU, UDEL, ERA40 reanalysis, ECHAM5 GCM and two simulations. Three peaks of temperature are observed from May to July with the maximum in the month of June over the NPI region. ECHAM5 captured the phase of annual cycle slightly higher than the observation from March to June with a good agreement in the month of July but the values are under predicted in January, February and from September to December over NPI. However magnitude of temperature is quite similar to observation over BB except for the overestimation in the months of June and April (Figure 10b). ERA40 reanalysis tends to underestimate the magnitude of annual cycle of temperature throughout the year over NPI.

Temperature peaks of two simulations are very close to the observations over WG and BB particularly in May, June and September. Annual cycle peaks in June, July and August for ERA40, RegCM4.3-ERA40 and RegCM4.3-ECHAM5 reproduced well with slight differences over the NPI region. RegCM4.3-ECHAM5 simulated the annual cycle of temperature more realistically as compared to driving GCM over the tree sub regions of the domain. The driving field and two simulations over predicted the area averaged temperature in the month of January-February and November-December as compared to the two observations over BB (Figure 10b). Over the WG the simulated monthly temperatures are lower than the observation from March to May and higher in all other months but closer to the observation as compared to the driving field (Figure 10c). Therefore regional climate model RegCM4.3 improved the simulation by providing the values close to the observation for area averaged annual cycle of temperature over three sub regions of South Asia.

The simulated annual mean precipitation (mm/day) over the three sub regions NPI, BB and WG are given in Figure 11. Over NPI the two simulations showed maximum precipitation in all months of the year and relatively minimum in July and August compared to the observation (Figure 11a). RegCM4.3 overestimated the winter precipitation and underestimated the summer precipitation over the three sub region as discussed in the previous section. The two driving fields tend to underestimate the annual cycle of precipitation over all selected regions except in June-July over WG and in May and November over BB with ECHAM5 GCM. RegCM4.3-ECHAM5 reproduced the monsoon precipitation well over WG but underestimated in April-October (Figure 11b). RegCM4.3-ERA40 leaned towards observation over WG and shows best agreement in the monsoon season (Figure 11b). The annual cycle of precipitation in summer season is underestimated and not reproduced well over Western Ghats with ERA40 reanalysis. Over BB generally good agreement is found between the observed and simulated data sets (Figure 11c), however CRU and UDEL monthly average precipitation peaks are higher especially in summer season. Large differences between the driving field and two simulations indicate that annual cycle of precipitation could be mostly driven by the internal dynamics and physics of RegCM4.3.

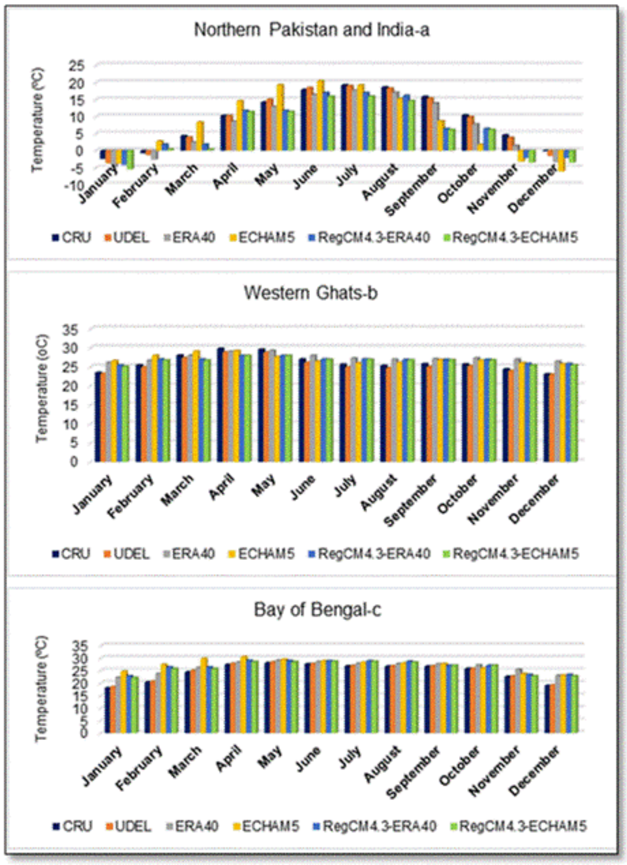

Figure 10: Annual cycle of monthly area averaged temperature (°C) over 3-sub regions (a) Northern Pakistan and India (NPI), (b) Western Ghats (WG), (c) Bay of Bengal (BB), for CRU, UDEL, ERA40, ECHAM5, RegCM4.3-ERA40 and RegCM4.3-ECHAM5 from 1971-2000

Conclusion

In the present study, we evaluated and compared the performance of ICTP regional climate model RegCM4.3 by simulating the present day climate (1971-2000) to reproduce the seasonal mean climatology and annual cycle for temperature and precipitation over South Asia.

Spatial and qualitative result are analyzed and averaged over the three selected region NPI, WG and BB. The model is driven by ECMWF ERA40 reanalysis and ECHAM5 GCM boundary forcing data set.

The main features of spatial distribution of temperature and rain fall are reproduced well with RegCM4.3, ERA40 and ECHAM5 with some exception over the Northern Pakistan and Central India because of the complexities of the domain and internal dynamics of the model. After downscaling from ECHAM5 GCM, regional climate model showed improvement in decreasing the cold winter bias over BB. This cold winter bias is also considerably reduced in both simulations compared to the driving field. RegCM4.3 mishandled the summer temperature over the mountain area of Northern Pakistan where the cold bias is significant.

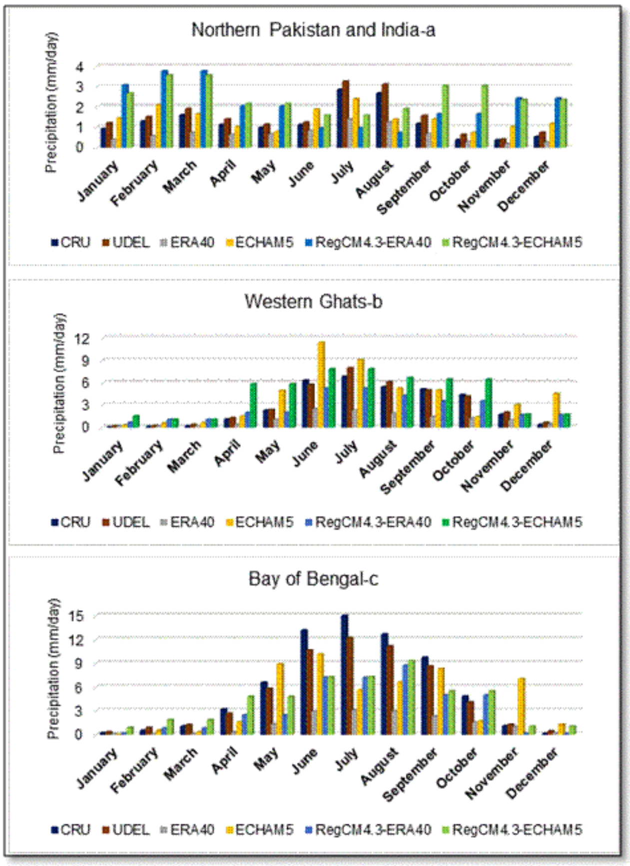

Figure 11: Annual cycle of monthly area averaged precipitation (mm/day) over 3-sub regions (a) Northern Pakistan and India (NPI), (b) Western Ghats (WG), (c) Bay of Bengal (BB), for CRU, UDEL, ERA40, ECHAM5, RegCM4.3- ERA40 and RegCM4.3-ECHAM5 from 1971-2000

Two observational data sets are not consistent and CRU is wetter compared to UDEL. Large differences are observed between the two driving fields. ERA40 is drier in winter over the whole domain and failed to reproduce the season mean precipitation. RegCM4.3 simulations show high precipitation intensity with wet bias in winter season over the foothills of HKH. However RegCM4.3 regional climate model captured and reproduced the main characteristics of the summer monsoon precipitation well. Biases in summer precipitation are significantly reduced from the driving field after downscaling with RegCM4.3.

Finally, we analyzed and compare the mean annual cycle of temperature and precipitation over NPI, WG and BB. The results showed that the performance of RegCM4.3 is better as compared to the two driving field with regard of temperature over WG and BB. While in the case of precipitation RegCM4.3 has mixed results for rainy and dry seasons over all sub regions of the domain. Generally mean annual cycle of precipitation is overestimated for two simulations over NPI and underestimated over the BB. The annual cycle of precipitation seems to be more linked with the regional processes based on the internal dynamic of RegCM4.3.

It is worth to note that dynamic downscaling improved the output of reanalysis and global GCM in many part of South Asian domain. Further investigation is required to take account the large differences between the driving field and RCM by using other available parameterization schemes.

Acknowledgements

The authors acknowledge the RegCM4.3 group of ICTP Trieste Italy, for providing the model with boundary forcing. This work has been supported by University of Nairobi-IRDC research grant. Technical assistance from Lin Jiao is much appreciated. The computational work is completed on the explorer 100 cluster system of Tsinghua National Laboratory for Information Science and Technology. Climate Research Unit (CRU) of University of East Anglia and University of Delaware (UDEL) are also acknowledged for providing observed data set of temperature and precipitation. European Centre for Medium Range Weather Forecast (ECMWF) and Max Plank Institute of Meteorology are also acknowledged for providing ERA40 and ECHAM5 data set respectively.

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