DOMAIN SIZE EXPERIMENT USING PRECIS REGIONAL CLIMATE MODEL FOR BANGLADESH

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ABSTRACT

Global climate models are used to predict plausible future climate based on various SRES Scenarios proposed by IPCC. However, meso-scale features (e.g. cloud formulation) which normally occurred within 10-50 km is often ill understood by GCM due to coarse domain (>250km). On the other hand, a regional climate model (RCM) is a dynamic downscaling tool that adds fine scale (high resolution) information to the large-scale projections of a global general circulation model (GCM). GCMs are typically run with horizontal scales > 250km whereas regional models can resolve features down to 50km or less. Many study shows that precipitation, one of the major diagnostic variables of the model, has been seriously underestimated by GCM. However, RCM can be one peninsula to this problem and help to study the regional scale hydrological and eco-system processes. While dealing with RCM simulation, it is essential to determine a suitable domain for that area which can successfully represent the meso-scale processes of that area for any RCM experiment. Larger domain size can cost computation time though they can cover major atmospheric circulation and processes over the area. Therefore, determining optimum domain size for an area of interest is essential and crucial for that region. In this study, experiments were conducted by PRECIS regional climate model on four domains of variable size over a period of 1981 to 1990 using ERA 40 Reanalysis data products. The goal of this study is to identify smallest size of the domain which can substantially reduce computational time and accurately present climate of Bangladesh. It has been found that the smallest domain is able to capture the mean monsoon precipitation pattern over India and Bangladesh. Such information can be helpful to study the future impact of climate change on the magnitude of extreme events such as floods and droughts etc., change of cropping pattern, and impact on livelihood and food security.

Keywords: *Climate Change, Domain, ERA40 Reanalysis data, GCM, PRECIS, RCM.*

1. INTRODUCTION

The fourth assessment report of IPCC showed that the mean temperature of the earth has been increasing at a rate of 0.74 degree centigrade per century (IPCC, 2007) which will affect major components of the ocean-atmosphere-biosphere processes. Global Climate Models showed that global warming will increase the intensity of extreme precipitation events (Allan and Soden, 2008). Regional projections also revealed that climate changes would strengthen monsoon circulation, increase in surface temperature, and increase the magnitude and frequency of extreme rainfall events. Regional climate models predict a large increase in annual precipitation although the more recent PRECIS run showed that the dry season is becoming drier and water deficit is increasing due to the population growth (Fung et al., 2006). Therefore, climate change will certainly bring an additional stress to rainfall pattern. However, one of the major problem of General Circulation Model (GCM) to represent meso-scale features within their coarse domain (>250km). However, Regional Climate Model (RCM) with a finer resolution (<50km), can successfully represent meso-scale features. Precipitation, one of the major diagnostic variables of the model, has been seriously underestimated by GCM. Study impact of climate change largely depends on the hydrological and eco-system process where precipitation is a major component. RCM can be one peninsula to this problem and help to study the regional scale hydrological and eco-system processes.

It is essential to determine a suitable domain for the area under observation which can successfully represent the meteorological parameters of that area for any RCM experiment. Larger domain size can cost computation time though they can cover major atmospheric circulation and processes over the area. Simulation on small domain is much faster than larger domains though there is a chance of not capturing major features of the area of interest. Hence, to determine optimum domain size for an area of interest is essential and crucial for that region. Bhaskaran et al. (1996) has conducted a domain size experiments over India to determine optimum domain which can capture the meso-scale climatic features over India. They have found an optimum domain, known as “Indian domain” with a size of 114 × 92 pixels and resolution of 50 km was able to represent the Indian monsoon successfully. But, the Indian domain is much larger if we consider the meteorological processes that influence the climate of Bangladesh. Therefore, there is a need of determination of an optimum domain which can represent climate of Bangladesh. In this study, we have selected four domains of interest to simulate by the PRECIS regional climate model. RCM has been simulated for domains over a period of 1981 to 1990 using Reanalysis data products of ERA 40.

2. METHODOLOGY

2.1 Regional Climate Modeling using PRECIS

A regional climate model (RCM) is a downscaling tool that adds fine scale (high resolution) information to the large-scale projections of a global general circulation model (GCM). GCMs are typically run with horizontal scales of 300km; regional models can resolve features down to 50km or less. This makes for a more accurate representation of many surface features, such as complex mountain topographies and coastlines. It also allows small islands and peninsulas to be represented realistically, whereas in a global model their size (relative to the model grid-box) would mean their climate would be that of the surrounding ocean.

In this study, PRECIS (Providing Regional Climates for Impact Studies), regional climate model was simulated over the large domains which cover Bangladesh and south Asia (PRECIS, 2010). PRECIS is based on the Hadley Centre's regional climate modeling system which was developed in order to help generate high-resolution climate change information for as many regions of the world as possible. RCMs are full climate models, and as such are physically based. They represent most if not all of the processes, interactions and feedbacks between climate systems components represented in GCMs. They produce a comprehensive set of output data over the model domain.

2.2 Lateral Boundary Condition Data

The quasi-real ERA 40 reanalysis data was used to derive the lateral boundary conditions of the simulation using three dimensional ocean-atmospheric coupled model (HadCM3Q) to generate prognostic variables over the simulation domains. PRECIS was simulated using the lateral boundary data of the prognostic variables generated by the HadCM3Q model to produce diagnostic variables (e.g. spatial precipitation, orographic height etc.) over the simulation domain during 1981-1990. Simulation grids were of 50km resolution over the Indian sub continent which includes Bangladesh.

2.3 Study Area

This study focuses on the selection of suitable domains in generating climatic information for Bangladesh. Figure 1 shows the various atmospheric circulations which effect climate of Bangladesh. Summer monsoon depressions are coming from south east parts of India towards the north east of Bangladesh. This depression causes major rainfall during the monsoon season (June to September) on the country and over the Ganges-Brahmaputra-Meghna (GBM) basins. Major floods of Bangladesh are mainly caused by heavy precipitations over the GBM basins during monsoon season. Monsoon rainfall generates runoff and finally conveys as flood water towards Bay of Bengal through Bangladesh by the three major river systems: the Ganges, Brahmaputra and Meghna.

Tropical thunder storms occurred during the pre-monsoon season (March-May) in the central parts of Bangladesh. Every year many sudden devastations occur which takes lives and damages houses, roads etc. due to pre-monsoon thunderstorms. Post monsoon (October to November) tropical thunder storms which is commonly known as Tropical Cyclones or Cyclones are formed in the Bay of Bengal, the largest bay in the world, forms the northeastern part of the Indian Ocean. Cyclones are usually characterized by inward spiraling winds that rotate counter clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere of the Earth. Coastal districts of Bangladesh faced heavy rainfall as an early impact of the major cyclone (above category 3). When cyclone hit on the coastal areas of Bangladesh, the damage in Bangladesh becomes extensive, including tin shacks flattened, houses and schools blown away and enormous tree damage.

Winter (November-February) western disturbance causes drought in the north-west part of Bangladesh and North part of India. Also, pre-monsoon (March-May) disturbance causes heavy rainfall and Flash floods in the north-east part of Bangladesh. Drought occurs in the north-west region receives consistently below average precipitation. It effects substantially on the ecosystem and agriculture of the affected region. Flash flood causes by heavy rain associated with a storm, hurricane, or tropical storm. What makes flash floods most dangerous is their sudden nature with no protection against being swept away causes human fatality.

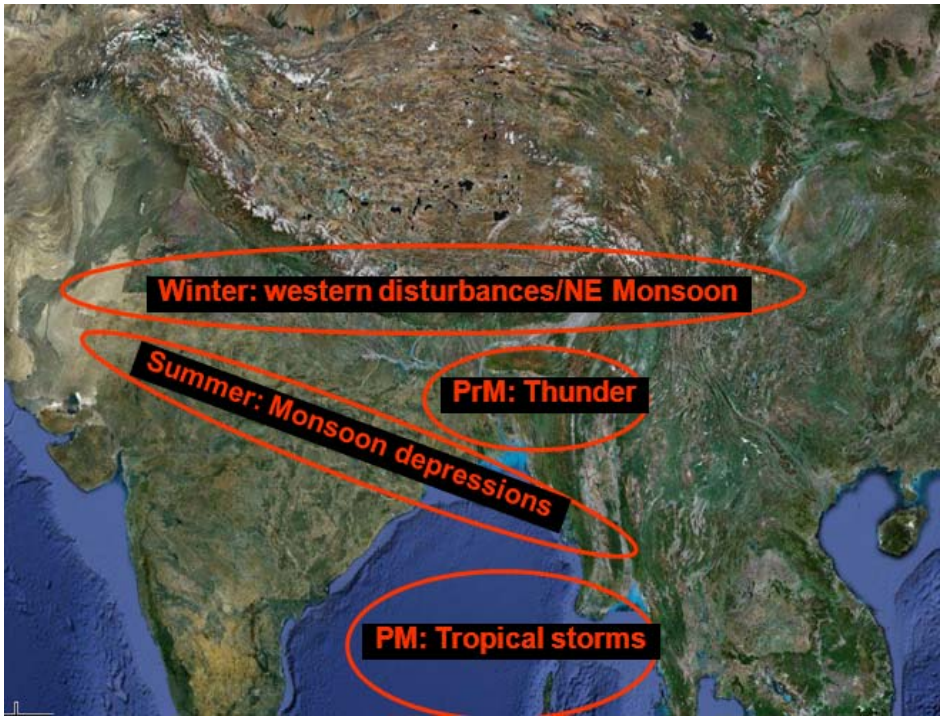

Figure 1: The major atmospheric circulations over the Indian subcontinents

Figure 2 shows the four domains of different sizes were used in this study. The first domain, RCM-1, is the smallest in size of 75 × 75 which has been selected considering the meteorological process over Bangladesh and Bay of Bengal. This small domain can be helpful by reducing computational time and effort for very fine resolution (25km) simulation purpose. The second domain, RCM-2, is bigger than first domain but smaller than other two domains. It can be helpful for studying meteorological processes over Bangladesh and hydro-meteorological processes that occurred over India and influence floods or flow in Bangladesh. The third domain, RCM-3 is in fact same as the Indian domain as discussed earlier. This should be able to capture the meteorological phenomenon of Bangladesh and India. The fourth domain, RCM-4 is the largest domain of among all the four domains. This domain should be able to capture all the large circulation patterns over Bangladesh and India. The main objective of this study is to see if the smallest domain is able to represent the meteorological conditions occurred in the largest domain. Small domain will be able to reduce computational time and effort significantly and will be helpful for reducing uncertainties involved in RCM simulation.

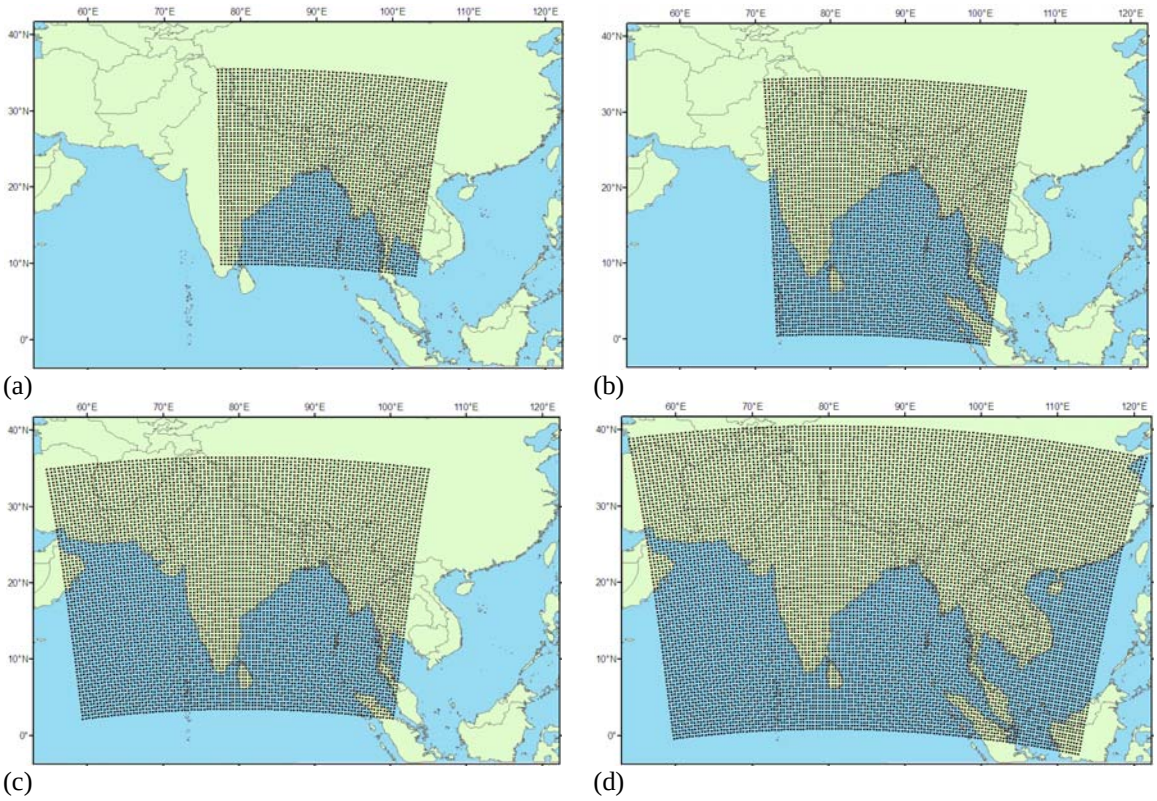

Figure-2: Domains (a) RCM-1, (b) RCM-2, (c) RCM-3 and (d) RCM-4

3. RESULTS

The land and sea masks of each of the four domains are shown in Figure 3. Blue color represents ocean and inland lakes (or water bodies) whereas green color represents land surface. The density of the green color depends on the elevation of the corresponding pixel. The orographic heights of the common validation area of all the domains are shown in Figure 4. The distribution of orographic height plays an important role in the monsoon precipitation for this region. Reddish color in the Figure 4 shows the Himalaya Mountains where the monsoon circulation gets obstructed and precipitation occurred on the mountains. Two major rivers: the Ganges and the Brahmaputra originated from the Himalayas and flowing through Nepal and India and finally they end their journey to the Bay of Bengal. The main cause of floods in Bangladesh in these two major rivers is the heavy precipitation during monsoon season (June-September) over their basins mostly (93%) in India. Hence, spatial distribution of the precipitation over the Ganges and Brahmaputra basins are important to study floods, normal river flow and low flow in dry season of Bangladesh. Figure 5 shows the spatial distribution of mean monsoon precipitation over the land in the four domains during the study period. The patterns of the distribution for all the domains have been found similar. Monsoon precipitation has been successfully captured in all the domains.

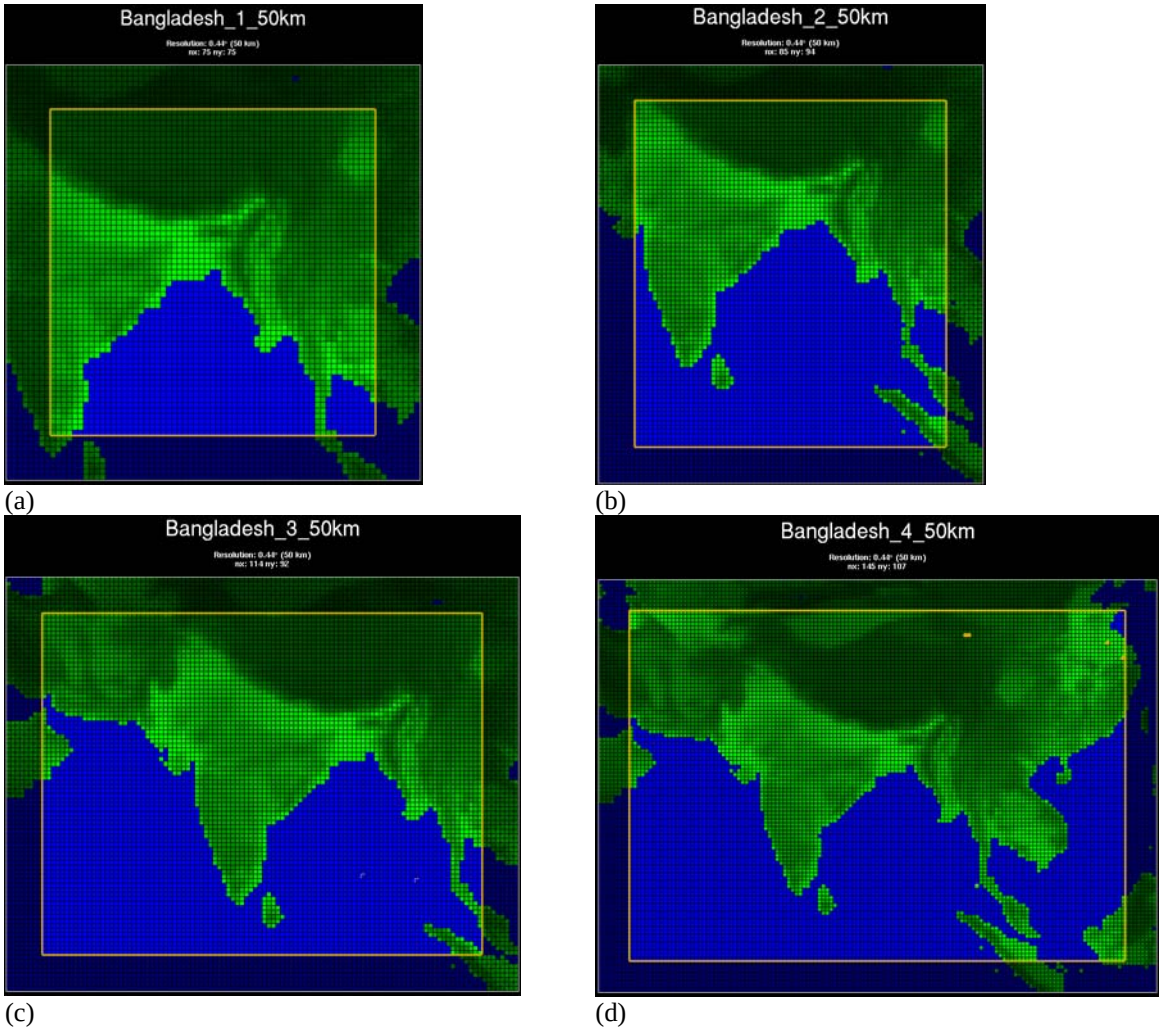

Figure-3: Land-sea masks of the topography of the selected domains (a) RCM-1, (b) RCM-2, (c) RCM-3 and (d) RCM-4.

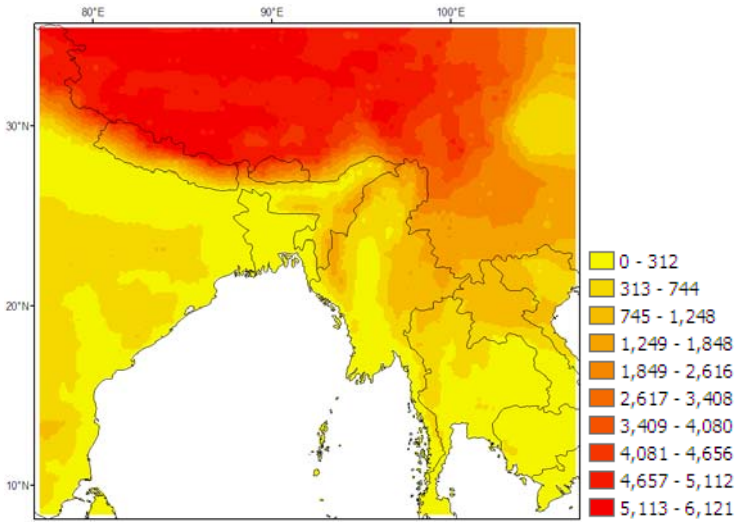

Figure-4: Orographic height for the common validation area which is RCM-1 domain.

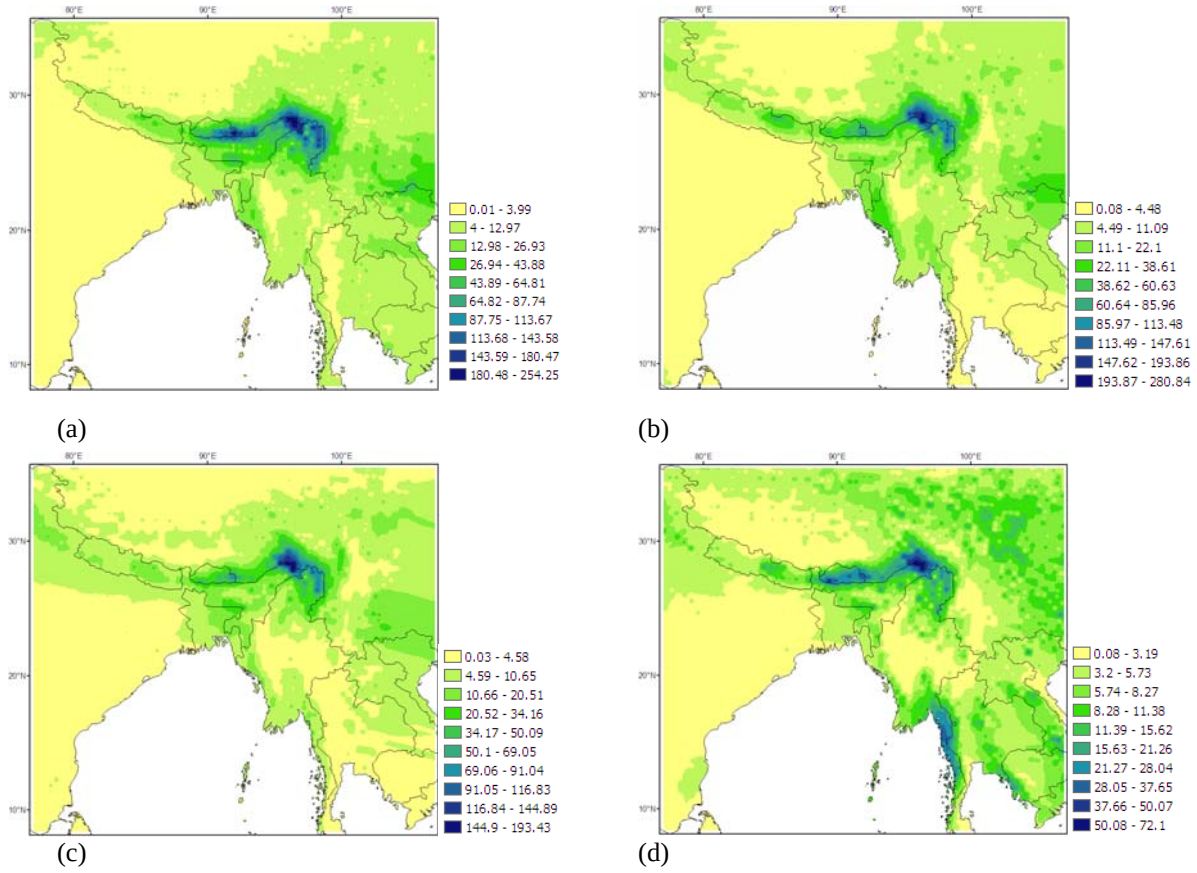

Figure-5: Spatial distribution of precipitation over land for June-September in (mm/day) for (a) RCM-1, (b) RCM-2, (c) RCM-3, and (d) RCM-4 domains.

4. CONCLUSION

Present study was comparing four different domains of variable sizes to identify the optimum domains which can represent the meso-scale features with the domain. The goal of this study is to identify smallest size of the domain which can substantially reduce computational time and accurately present climate of Bangladesh. It has been found that the smallest domain (RCM-1) is able to capture the mean monsoon precipitation pattern over India and Bangladesh. Such information can be helpful to study the future impact of climate change on the magnitude of river flow and extreme events such as floods and droughts etc.

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