STATE OF THE ART CLIMATE CHANGE ASSESSMENTS FOR SRI LANKA FROM CMIP5

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The characterization of future climate change for Sri Lanka is critical for assessment of impacts on various sectors, regions, systems, and for formulation of policies and practices to adapt to climate change. Such attribution requires detailed understanding of historical and ongoing climate variability, extreme events, and decadal change. The work in Sri Lanka should be contextualized in terms of South Asia and Indian Ocean climate variability and its change. In Sri Lanka, the issues of fine-spatial scale are critical given the rapid variation in climate over relatively small distances. Projections of climate change should include indications of confidence levels and assessment of uncertainty.

Climate change assessments in the near-term can be based on understanding long-term decadal change from observations and proxies of climate such as the size of tree rings. Climate systems could also be projected by developing computer models through understanding the physics and incorporating the consequences of recent human action. But there are major limitations in the computer modeling approach primarily due to the complexity of the atmospheric system, the limitations of the historical observations, and the characterization of the processes such as cloud physics. Understanding the climate system and projecting into the future considering the impact of human action is the methodology that is still commonly used to project future climate. Under this framework, global climate models from many science centers in advanced countries produce global projections based on common baselines. These models have much in common but also have similar weaknesses. The long-term projections unfortunately cannot be verified on an ongoing basis. Some of the uncertainty can be captured by examining the outputs from all the models. Some of the skills of the models can be evaluated for different regions and seasons by investigating the ability of these models to reproduce past climate. It is thus essential to remember these problems in uncertainty assessments.

Current Problems in Climate Change Assessments

Climate Change assessments for Sri Lanka have been undertaken from time to time but not in a systematic and sustained way. The methodologies have been only based on downscaling the results from global scale models, where the general skill of these models over the region is not being investigated. Indeed, the past projections and the current projections from these models are for a wetter and warmer future. However, these projections have not been borne out in the last 15 years – thus calling into question the skill of the General Circulation Models (GCMs) for this region. In addition, the various projections have been inconsistent when it comes to rainfall projections. Thus it is imperative that these issues are addressed rather than simply just downscaling from global climate models without further investigation.

Climate Change Projection Methodologies using GCMs

Currently the climate models use underlying physics of the atmosphere along with anticipated changes (in forcing such as of Greenhouse gas emissions, changes in human activity) into the future, as the main tool to project climate change. At present, Global Climate Models (GCMs) are run for typically at a resolution of about 100- 250 km for the entire globe due to the limitations in computing power and availability of data. At such course resolution, these models do not capture critical climate factors such as cloud formation or details of the high-mountain topography which can have profound influences. The methodologies whereby results that are produced at such large scale are interpreted for finer scale is referred to as downscaling. The two broad classes of downscaling methodologies are statistical and dynamical, which have their limitations (Zubair et al. 2004, Qian and Zubair, 2010). Such downscaling is critical for Sri Lanka given its quite varied climate and topography.

As part of the global climate change assessment process, the Coordinated Model Inter-Comparison Program (CMIP) has produced archives of simulations, using leading General Circulation Models, and common input data and standardized domains referred to as CMIP5. Outputs of CMIP5 GCMs were assessed in the latest report by the IPCC- AR5.

Past Projection Studies for Sri Lanka

Previous studies had been conducted to project the future climate based on Carbon Dioxide emission scenarios developed by the IPCC in their Special Report on Emission Scenarios (IPCC-SRES) (IPCC, 2000). Climate predictions for Sri Lanka have been done only for SRES scenarios A1F1, A2, B1 and B2. In a study done using GCMs by HadCM3, CSIRO and CGCM predict an increase in temperature by 2 – 3 ^{0}C under A1F1 scenario, 0.9 – 1.4 ^{0}C increase under B1 scenario and 1.7 – 2.5 ^{0}C increase under A2 scenario at the end of the 21st century (Basnayake, et al., 2004). Another study which uses the HadCM3 model has predicted 1.6 ^{0}C and 1.2 ^{0}C increase in temperature by 2050, under A2 and B2 scenarios respectively (De Silva, 2006).

Prior assessments have shown consistency across global climate models for temperature projections. There is greater variability among the projections in regard to precipitation (Eriyagama, et al., 2010); (Mahanama & Zubair, 2011). HadCM3 and CSIRO models have predicted higher southwest and northeast monsoon precipitation under A1F1, A2 and B1 scenarios, but CGCM model has predicted lower rainfall in these two monsoon seasons for the future (Basnayake & Vithanage, 2004) (Eriyagama, et al., 2010). Another study has predicted higher southwest monsoon rainfall and lower northeast monsoon rainfall using HadCM3 GCM and A2 scenario (De Silva, 2006). Similar prediction has also been made using the same GCM but with A1 and B1 scenarios (Basnayake & Vithanage, 2004). Selected GCMs from CMIP3 archives under A2 and B2 scenarios has also been studied previously (Dharmarathna, et al., 2014), (Mahanama and Zubair, 2011).

Climate Change Projections for Sri Lanka from CMIP5 from FECT

FECT has tried to bring best practices into generating climate change projections. The work that has been undertaken is not completed but it does much better at addressing the quality and uncertainty of the assessments (Zubair et al. 2014, Zubair et al., 2015).

Climate change projections for Sri Lanka for the 21st century has been produced using 20 CMIP5 GCMs, and latest CO_2 concentration pathways adopted by the IPCC for AR5 called Representative Concentration Pathways (RCP). Out of 4 possible concentration pathways categorized based on possible range of radiative forcing by year 2100 relative to pre-industrial values (van Vuuren, et al., 2011) 2 were used (RCP4.5 and RCP8.5). Here RCP8.5 is the worst case CO_2 emission scenario. Projections for the 21st century were done for three 30-year periods, 2010- 2040, 2040- 2070 and 2070- 2100.

While detailed seasonal and regional projections have been undertaken for locations across Sri Lanka, here, only results for Batalagoda located in the Kurunegala District north-western province is presented, under the worst case CO_2 emission scenario in the 2040- 2070 period which was defined as the Mid-Century. The results presented here show the range of variability of projections for rainfall and temperature among the different models.

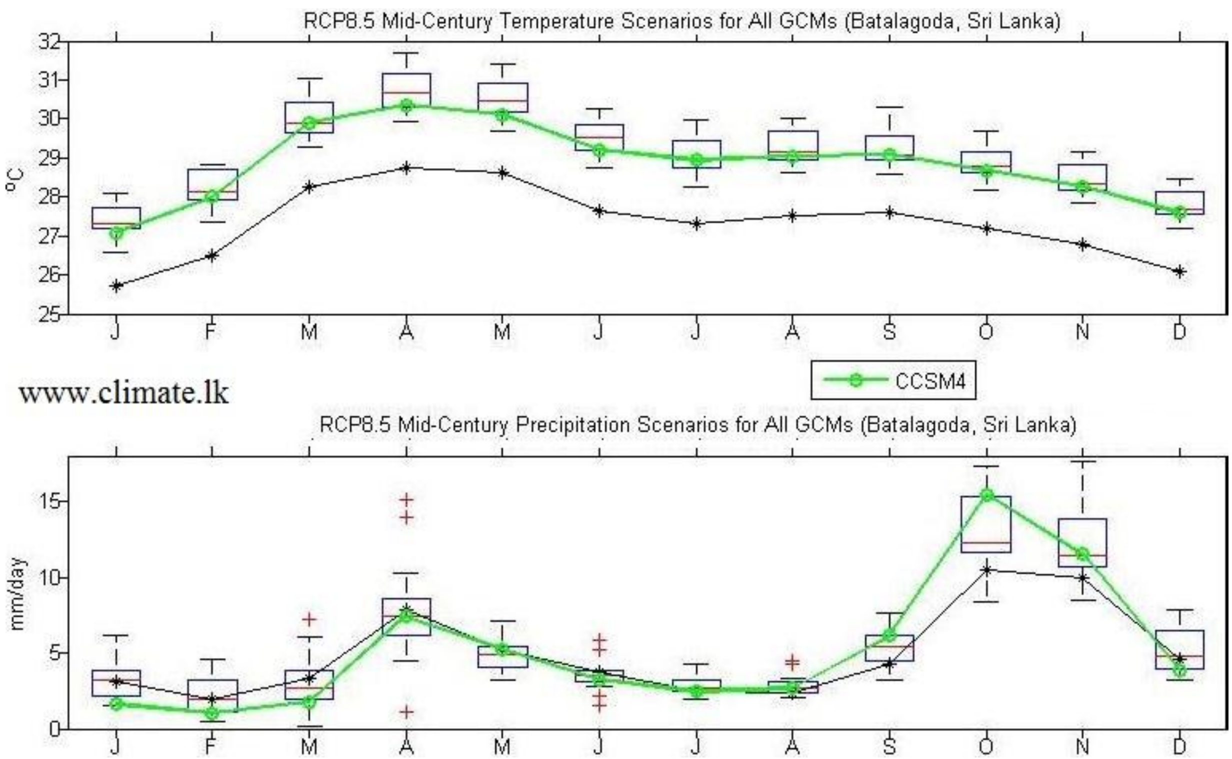

Figure 1: Projected Temperature (top) and Rainfall (bottom) Climatologies for 2040- 2070 of all GCMs under RCP8.5 for Batalagoda. Black line with stars shows the climatology of the baseline (1980- 2010) period while the green line shows CCSM4 GCM.

Figure 1 shows temperature and rainfall climatologies in Batalagoda during 1980- 2010 by the black solid line and future projections of 20 selected GCMs of each month by box and whisker plots. Box and whisker plots provides information about the variability of 20 future projections for each months and thus the uncertainty. In the temperature prediction, the variability of 20 predictions by 20 GCMs are similar throughout the year which ranges from 1- 2.5 ^{0}C above the historical mean temperature each month. Contrary to the temperature prediction, the rainfall prediction shows variability of different magnitudes among 20 predictions in different months of the year. June to August has the lowest variability and also the lowest expected change of rainfall magnitude while September to December has the highest variability and the highest change in rainfall.

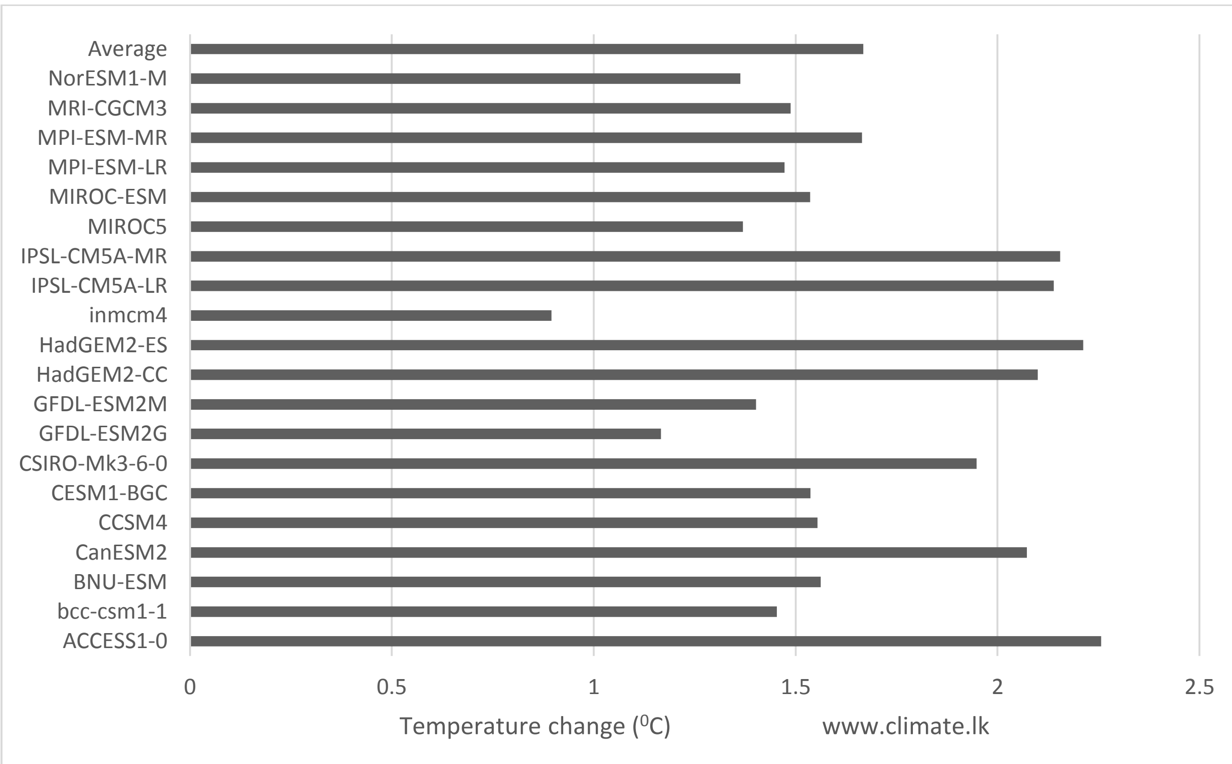

Figure 2: Projected annual Maximum Temperature departures of 20 GCMs from the historical average during the Mid-Century under RCP8.5 in Batalagoda, Sri Lanka.

Figure 2 shows projected maximum temperature changes by 20 GCMs in the Mid-Century. While some models predict an increase as low as 0.9 ^{0}C, some predict more than 2^{0}C increase in maximum temperature. This is a good example for the uncertainty associated with predictions using GCMs.

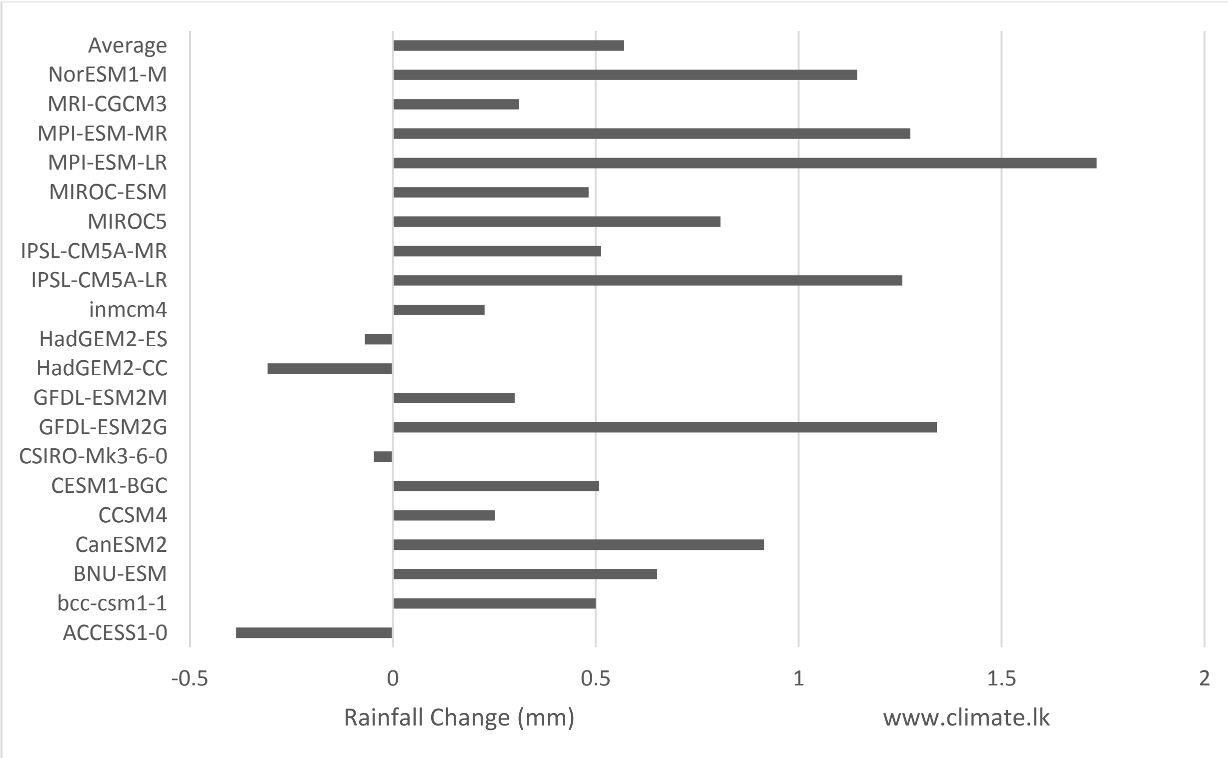

Figure 3: Projected annual Rainfall departures of 20 GCMs from the historical average during the Mid-Century under RCP8.5 in Batalagoda, Sri Lanka.

According to Figure 3, some models predict that the rainfall will decrease in the future, while the majority of models predict that rainfall will increase.

There is a very high uncertainty regarding the magnitude of which the rainfall shall change in the future. About half of the models predicting an increase in rainfall expect that the change will be below 0.5 mm while one fourth of models predict an increase excess of 1 mm in the Mid-Century.

Following analysis as in (Zubair, et al., 2015) 5 , GCMS (CCSM4, GFDL-ESM2M, HadGEM2-ES, MIROC5, MPI-ESM-MR) with better simulations for the larger region were selected for further analysis and the summary statistics for RCP8.5 scenario in Batalagoda are tabulated as follows (

Table 1). The standard deviations of projected means of 5 GCMs were found to be higher than that of the historical mean.

Table 1: Daily mean, standard deviation and the confidence interval of mean, of maximum and minimum temperatures and rainfall in Batalagoda. Historical calculations are done using data from 1980- 2010 and calculations for other 5 GCMs are done using projected future values during 2040-2070.

Scenario	T_{MAX} (^oC)			T_{MIN} (^oC)			Precipitation (mm)		
	Mean	SD	CI	Mean	SD	CI	Mean	SD	CI
Historical	31.3	1.9	± 0.03	23.4	1.8	± 0.03	5.0	13.2	± 0.24
CCSM4	32.8	1.9	± 0.03	24.9	1.8	± 0.03	5.2	14.6	± 0.27
GFDL-ESM2M	32.7	2.1	± 0.04	25.0	2.0	± 0.04	5.3	15.0	± 0.28
HadGEM2-ES	33.5	2.0	± 0.04	25.9	1.9	± 0.03	4.9	13.6	± 0.25
MIROC5	32.7	1.8	± 0.03	24.9	1.8	± 0.03	5.8	15.5	± 0.29
MPI-ESM-MR	32.9	2.0	± 0.04	25.3	1.8	± 0.03	6.3	17.2	± 0.32

Results under both RCPs show that both minimum and maximum temperature shall increase in the future. Temperature increase under higher CO_2 emission scenario (RCP8.5) is about 0.5 ^0C higher than RCP4.5 in the Mid-Century and is about 1.5 ^0C higher by the end of the 21st century. Majority of prediction models expect an increase in rainfall, but there is high uncertainty about the magnitude which it will increase. When comparing the results for rainfall predictions under RCP4.5 and RCP8.5, the expected magnitude of change is the same but the variability of the prediction is higher under the high emission scenario.

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