PROJECT TERMINAL REPORT

Project Title: Assessments of Climate Change Impacts and Mapping of Vulnerability to Food Insecurity under Climate Change to Strengthen Household Food Security with Livelihoods' Adaptation Approaches (AMICAF)
Step 1- Assessment of Climate Change Impacts on Agriculture

Program: FAO-AMICAF Philippines

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Project Leader: **FLAVIANA D. HILARIO, PhD**
Acting Deputy Administrator for Research and Development

Assistant Project Leader: **EDNA L.JUANILLO**
Officer-In-Charge, Climatology and Agrometeorology Division

Support Personnel/s: **ANTHONY JOSEPH R. LUCERO**
Officer-In-Charge, Climate Monitoring and Prediction Section

ANALIZA S. SOLIS
Senior Weather Specialist

JORYBELL A. MASALLO
Weather Specialist II

RUSY G. ABASTILLAS
JOSEPH Q. BASCONCILLO
CHERRY JANE L. CADA
REMEDIOS L. CIERVO
Weather Specialist I

Contact Details: Climate Monitoring and Prediction Section
Climatology and Agrometeorology Division
(+02) 434-0955
pagasa_climps@yahoo.com

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Overview

Based on Intergovernmental Panel on Climate Change (IPCC, 2007b), changing climate is projected to have a number of impacts, including possible water shortages, decreased agricultural production and food security. With these considerations a joint project undertaking was forged with the Philippines and the FAO-AMICAF with the cooperation of the University of Cantabria in Spain. The project aims to assess vulnerability of households to food insecurity through the use of a tool called MOSAICC.

MOSAICC is an acronym for Modelling System for Agricultural Impacts of Climate Change. It is a system of models and utilities designed to carry out inter-disciplinary climate change impact assessment on agriculture through simulations. The system is composed of four major components – 1) Statistical downscaling portal primarily used to downscale Global Circulation Models (GCM) data to weather stations networks, 2) a hydrological model for estimating water resources for irrigation in major basins, 3) a water balance-based crop models to simulate crop yields under climate change scenarios, and finally 4) a Computable General Equilibrium model (CGE) to assess the effect of changing yields on national economies.

The project study was undertaken by four major institutions namely the Philippine Atmospheric Geophysical and Astronomical Services Administration (**PAGASA**), the University of the Philippines National Institute of Geological Sciences (**UP NIGS**), the Department of Agriculture (**DA**) through the Philippine Rice Research Institute (**PhilRice**), and the National Economic Development Authority (**NEDA**) and two other cooperating institutions – 1) the Food and Nutrition Research Institute (**FNRI**) and the 2) Community Based Monitoring System (**CBMS**).

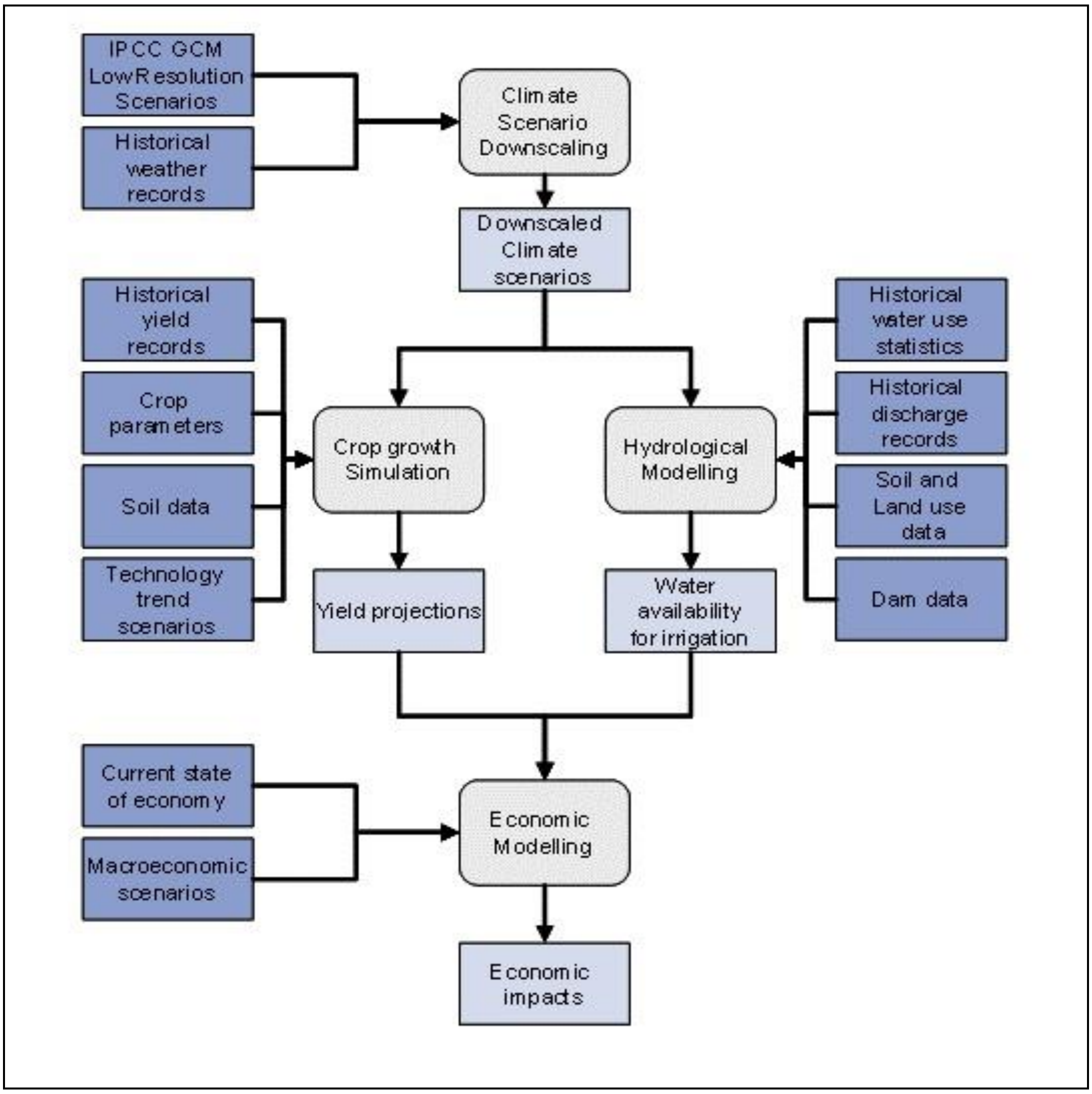

Figure 1. Project workflow under MOSAICC configuration

The work plan was implemented through a series of workflow described in Figure 1. PAGASA undertook the first phase of the work plan which is the climate scenario downscaling. The first few months of the actual work were very challenging due to calibrations made with the software and hardware. Later, it became necessary to do the work in the University of Cantabria where two technical staff from PAGASA did the actual computer runs.

Results obtained from the computer runs were compiled, processed, and provided to next participating institutions for further studies. PAGASA, with the generous cooperation and assistance of our Japanese consulting scientists, completed the required job needed for the finalization of climate change scenarios from 2011 to 2040. Results of downscaling experiments were presented to the National Steering Committee during a conference held in

January at the Cocoon Boutique Hotel in Quezon City. In a subsequent workshop under the Community Based Monitoring System for Local Government Units, downscaling results were presented as possible basis for Climate Change Adaptation and Disaster Risk Reduction (CCA/DRR) program.

Program Background

FAO-AMICAF Philippines and PAGASA have an existing partnership to provide climate data based on climate projections statistically downscaled from FAO-MOSAICC portal. The project started in 2011 and is expected to end in the latter part of 2014. Several workshops and meetings have already transpired between FAO-AMICAF and PAGASA on the progress of downscaling as well as provision of projected data to their partners. In April 2014, a collaborative work between FAO-AMICAF and PAGASA on the utilization of Coupled Model Intercomparison Project Phase 5 (CMIP5) will commence. This project aims to provide relevant and updated climate information for national socioeconomic policy making.

INTRODUCTION TO PHILIPPINE CLIMATE AND CLIMATE CHANGE SCENARIOS

During the 4th Assessment Report, the IPCC utilized more than twenty (20) global coupled atmosphere-ocean general circulation models (AOGCMs) to project future climate changes by various scenarios (IPCC 2007a). These AOGCM simulations were performed under the third phase of the Coupled Model Intercomparison Project (CMIP3) of the World Climate Research Programme (WCRP). These results reduced the error between models through averaging the results of numerous models. However, it is very evident that the coarse grid resolution of the models of about 100 km to 400 km has a detrimental impact on the results of projecting mean future climate including extreme weather events. Statistical downscaling can be one of the approaches to project the modification by climate changes for adaptation studies and measures and to improve poor prediction of precipitation. Statistical downscaling methods establish an empirical statistical relationship between the atmospheric circulation and precipitation, and then infer local changes by means of sensibly projecting the large scale information on the local scale [Zorita and von Storch, 1999].

Based on IPCC (2007b), changing climate is projected to have a number of impacts, including possible water shortages, decreased agricultural production and food security.

Overview of Philippine Climate

The climate of the Philippines is predominantly influenced by its geographical location and the topographic features of its landscape with several islands, mountain ranges, and coastal plains; and wind systems as a result of the seasonal differential heating of neighboring continents and oceans. Figure 2(a) shows the topographic map of the Philippines outlining the three major islands of Luzon, Visayas and Mindanao and the mean annual rainfall distribution (mm/day) averaged from 1979-2010 2(b).

Observed rainfall could be attributed to different mesoscale phenomena, such as the Inter-Tropical Convergence Zone (ITCZ), the tail end of cold front, the Northeast (NE) monsoon (locally known as ‘Amihan’ from April to September), Southwest (SW) monsoon (locally known as ‘Habagat’ from October to March), semi-permanent high pressure systems, tropical cyclones and El Nino Southern Oscillation (ENSO) variability [*Jose et al.*, 2000].

In general, the climate of the Philippines can be described as humid equatorial, with marked

high temperatures but the differences between the maximum and minimum temperatures does not vary much; and tropical maritime, with uneven rainfall distribution throughout the year and marked high annual rainfall values. Figure 3 depicts the seasonal rainfall distribution during the two distinct monsoon systems.

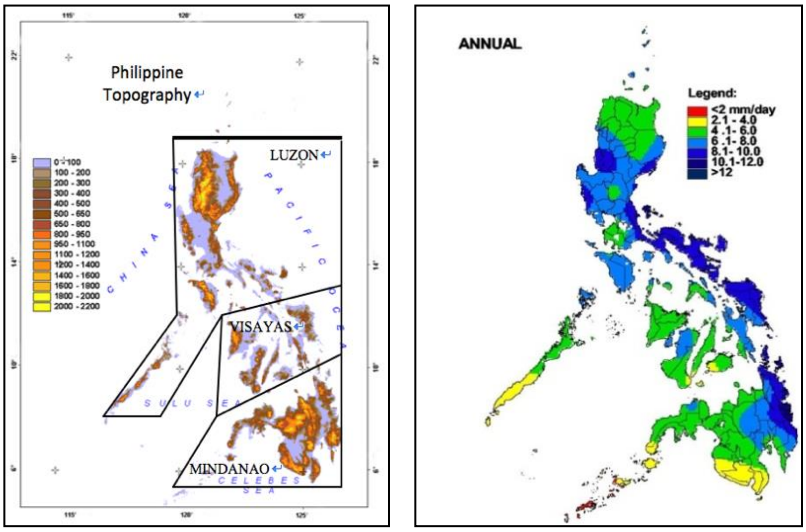

Figure 2. (*a*) Topographic map of the Philippines with delineation of main islands of Luzon, Visayas and Mindanao; (*b*) station-scale interpolated mean annual rainfall distribution (1979-2010) in mm/day.

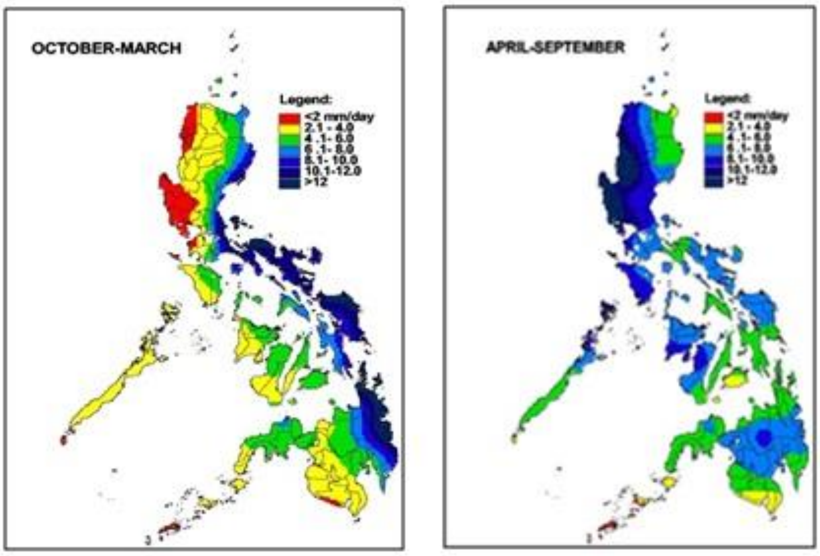

Figure 3. Seasonal rainfall distribution during (*a*) SW monsoon and (*b*) NE monsoon. Note that Plots were made out of APHRODITE (Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation of Water Resources) gridded station dataset (Yatagai et.al, 2012)

The onset of rainy season occur rather abruptly across the western Philippines around mid-May on average and is associated with the set-up of a ‘‘classical’’ monsoonal circulation with low-level easterlies subsequently veering to southerly, and then southwesterly. The onset date is defined using a local agronomic definition, namely the first wet day of a 5-day period receiving at least 40 mm without any 15-day dry spell receiving <5 mm in the 30 days following the start of that period (Moron et al 2008). Figure 4 shows the mean onset date of rainy season based on station and CMAP rainfall. Note however, rainfall during this season is also the most difficult parameter for the GCMs to simulate (Gadgil and Gadgil 2006).

Tropical cyclone tracks over the Philippines exhibit prominent seasonal variations from January to December (Figure 5). Normally, the intraseasonal variations of tracks are subject to year-to-year variability. Tropical cyclones spawned in this region generally track westward and may later turn northwest, first affecting the Philippines and then moving on to the Asia mainland or recurving northeastward towards Japan. The peak of the typhoon season is July through October, when nearly 70% of all typhoons develop (Cinco et al. 2006).

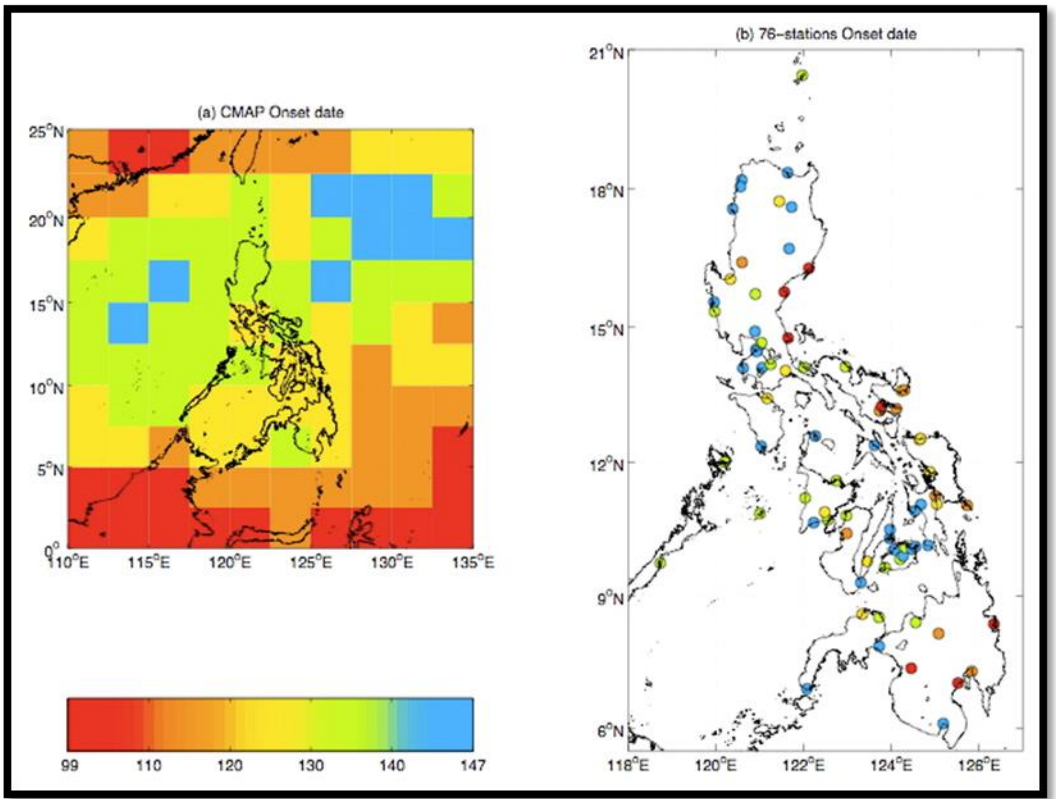

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Figure 4. Distribution of onset date based on CMAP (left figure) and station (right figure) rainfall. Color bar show days of the year, January first being day 1.

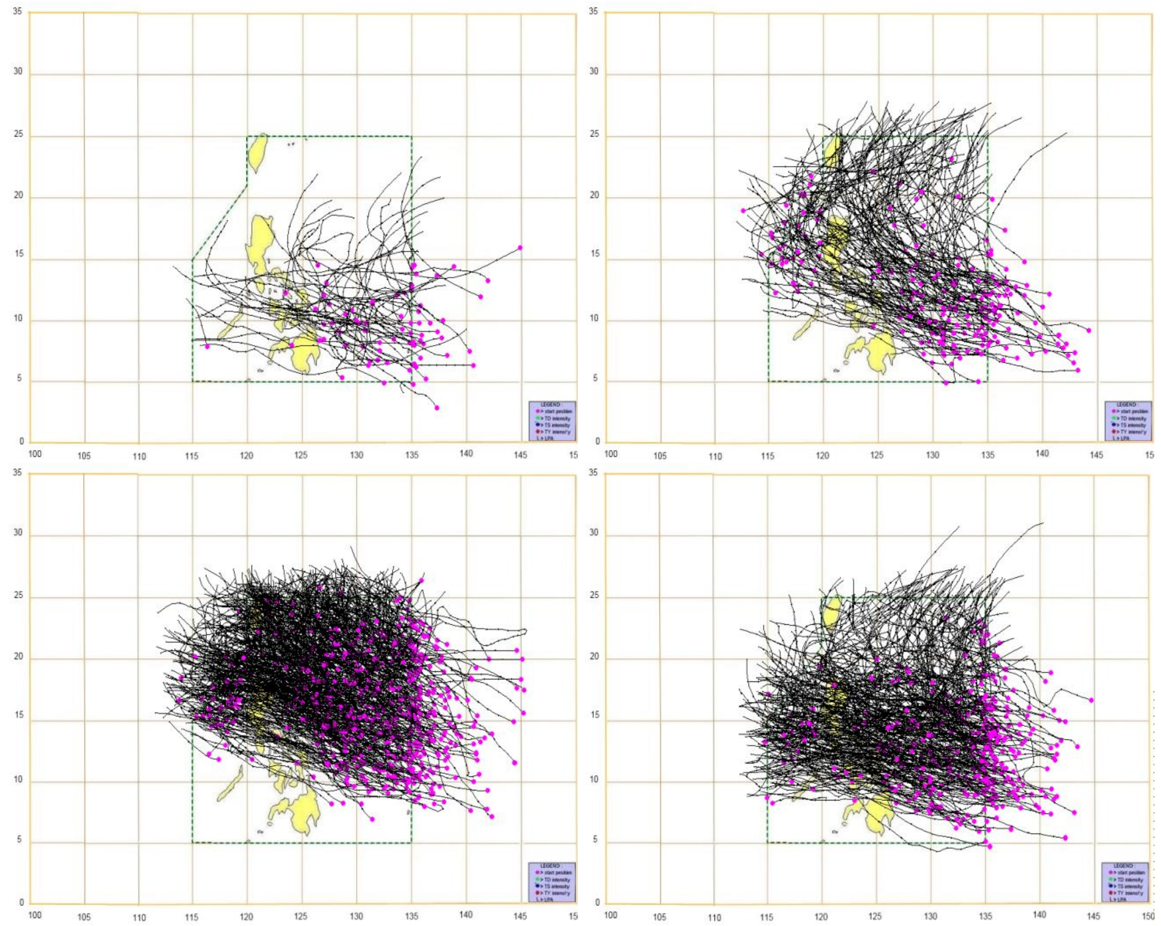


Figure 5. Actual seasonal tracks of tropical cyclones (a) DJF (b) MAM (c) JJA (d) SON from 1951-2013 in the Philippine Area of Responsibility (PAR). Data source: Tropical Cyclone Guidance System (TCGS), Weather Division, PAGASA)

The influence of ENSO as exhibited by El Niño and La Niña conditions in the central and eastern equatorial Pacific (CEEP) has contributed much to the rainfall variability and unusual behavior in the local climate [Jose et al., 2000]. It has a strong impact to agricultural production and better plans are needed for disaster risk reduction and management (DRRM) and climate change adaptation (CCA). The 1997-1998 El Niño event is considered to have the strongest impact on record over the past 50 years, surpassing the 1982-1983 El Niño episode. Lyon et al. (2006) showed that the seasonal reversal of ENSO rainfall in the Philippines exist, where between July and September, above median rainfall is observed over north central Philippines during El Niño before anomalously dry situations become apparent between October to December. Conversely, below-median summer rainfall occurs at several stations before the onset of anomalously wet conditions from October to December during La Niña.

Observed Trends in the Philippines

Trend analysis made by PAGASA showed that the observed mean temperature in the Philippines has increased by 0.64 ºC during the last 60 years (1951-2010). Daytime maximum temperatures have increased by 0.36ºC, while greater increase was more evident in observed minimum temperatures, in which it has increase by 1ºC during the last 60 years. However, problems remain in attributing observed temperature changes at local scales since natural variability is relatively larger making it harder to make distinctions whether changes were due to natural variability or due to external forcing. Also, uncertainties in local forcing such as due to land-use change and feedbacks also make it difficult to estimate the contribution of increase in greenhouse gases to observe small-scale temperature changes (IPCC, 2007). Figure 6 shows the observed trends in mean, maximum and minimum temperatures over the Philippines compared with the 1971-2000 normal values.

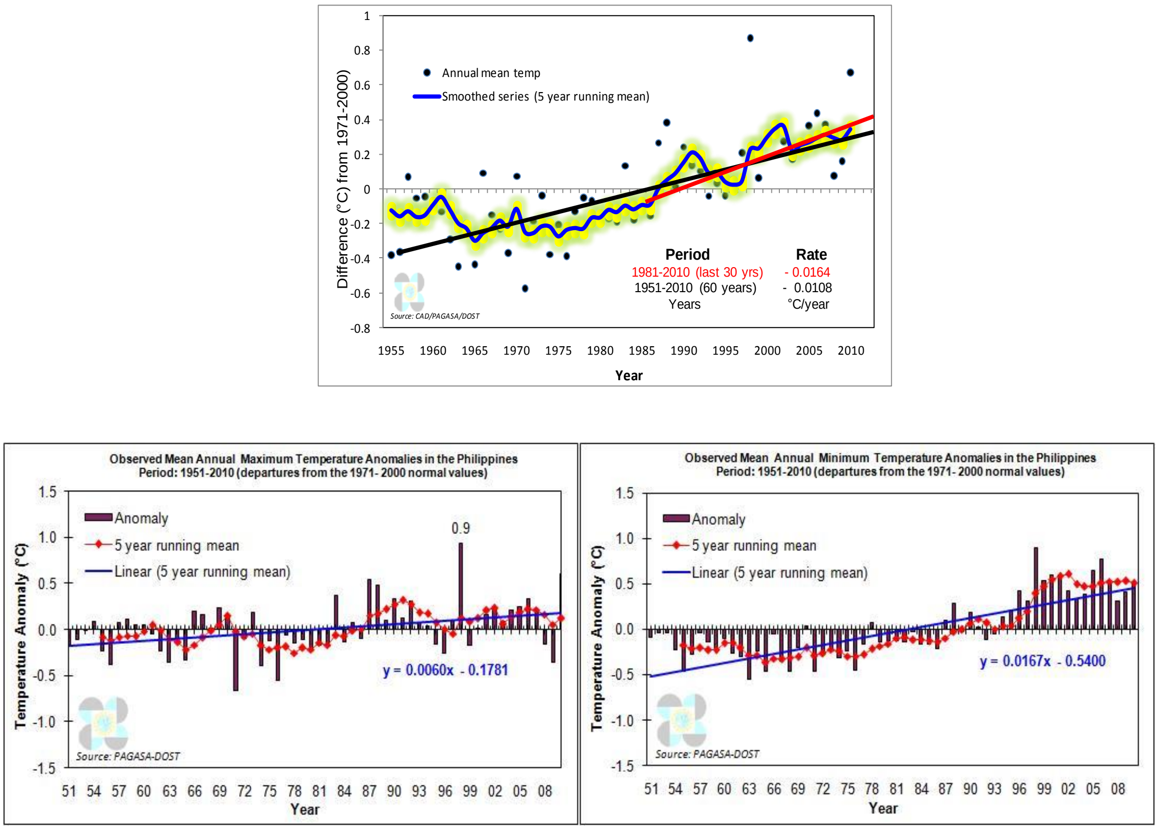


Figure 6. Observed Temperature Anomalies in the Philippines (a) Mean (b) Maximum (c) Minimum Period: 1951-2010 (departures from the 1971-2000 normal values)

Climate Projections in the Philippines

Projections of seasonal changes in rainfall and temperature as well as changes in the frequency of extreme events both at the national and provincial level were generated under this project. All climate projections cover the years 2011-2040 centered in year 2025.

Data and Emission Scenarios

The new ERA-interim (ECMWF Re-analyses Interim) (1.5° x 1.5°) gridded reanalyses of European Centre for Medium-Range Weather Forecasts (ECMWF) described by Uppalla (2008) was used as pseudo-observations fed into the climate data processing tools of the FAO-MOSAICC portal. This data is the third generation ECMWF reanalysis product carried out with higher horizontal resolution and a 4D variation analysis. Furthermore, ERA-interim was developed with better formulation of background error constraint, improved model physics, better bias correction, and new ozone profile from 1995 onwards (Simmons et al. 2007, Uppala et al., 2008). This could lead to good quality simulations due to the presence of better quality driving fields. The period 1979-2010 of ERA-Interim was used in this project.

The IPCC has developed and used emissions scenarios to assess future climate change. The 2000 Special Report on Emissions Scenarios (SRES) was developed to provide the basis for assessing future climate change and possible response strategies (Nakicenovic et al 2000:598; van Vuuren et al. 2006). The SRES scenarios are storylines depicting different assumptions of driving forces of greenhouse gases (GHGs) and sulfur emissions such as demographics (population), economics, technology, emissions and land use. Each of the six illustrative scenarios (see Figure 7) represents a specific quantitative interpretation of one of four storylines; scenarios with same storyline comprise a scenario “family” (Nakicenovic et al. 2000).

The A1 storyline assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies. A1 is divided into three groups that describe alternative directions of technological change: A1F1 emphasizes the use fossil fuels as energy source; A1T focuses on non-fossil fuels and; A1B describes a balance of the two aforementioned scenarios. Meanwhile, B1 describes a convergent world, with the same global population as A1, but with more rapid changes in

economic structures toward a service and information economy. A2 describes a very heterogeneous world with high population growth, slow economic development, and slow technological change. No likelihood has been attached to any of the SRES scenarios. (WGIII TS.1, SPM). In this study, A1B and A2 emission scenarios were used. Figure 7 shows global GHG emissions illustrating 6 SRES marker scenarios from IPCC 4th Assessment Report. It should also be noted that Figure 7 indicates the divergence of Global GHG emission between A1B and A2 happening in 2030-2035.

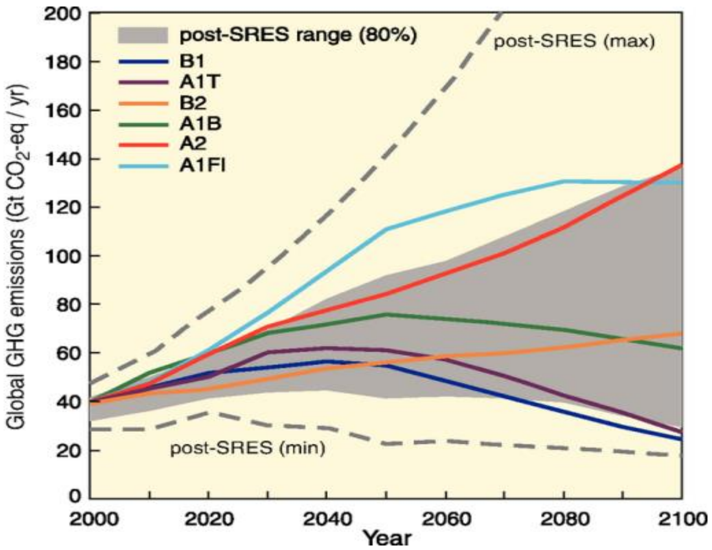


Figure 7. Global greenhouse gas emissions (in GtCO2-eq per year) depicting six illustrative SRES marker scenarios. The emissions include CO2, CH4, N2O and F-gases. Source: IPCC, WGIII).

Three global circulation models (GCMs) were used in climate change projections. These include Bergen Climate Model Version 2 (BCM2), Centre National de Recherches Météorologique Climate Model Version 3 (CNCM3), and Max Planck Institute ECHAM Version 5 (MPEH5). Hereto forth, these models will be referred to their respective acronyms or GCM in general. Table 1 shows the years projected by each model for each scenario. Some years of 20C3M GHG emissions are missing for BCM2 and MPEH5. 20C3M refers to 20th century GHG concentration and natural forcing, which is used as a control climate of previous years.

Table 1. Years covered by 20C3M and SRES of each GCM

DATASET	BCM2	CNCM3	MPEH5
ERA-Interim	1979-2010		

20C3M	1971-1999	1971-2000	1971-2000 (excluding 1973, 1984, 1992)
A1B	2011-2050	2011-2050	2011-2050
A2	2011-2050	2011-2050	2011-2050

Seasons are grouped into four classification based on the seasonality of Northern Hemisphere. These include (1) DJF: December-January-February or winter, (2) MAM: March-April-May or spring, (3) JJA: June-July-August or summer, and (4) SON: September-October-November or autumn.

Projected changes are relative to the baseline years (1979-1999) derived from ERA-Interim. These baseline years are used for all GCM 20C3M. Changes in rainfall are expressed in percent change (% change) while changes in temperature are expressed in absolute change (°C). This means that any changes either in percent or absolute will be added to the baseline years to reflect the change in baseline values. For example, a 3% projected change in rainfall directly translates to a 3% baseline change in rainfall while a 0.3°C projected change in temperature results to 0.3°C in baseline change in temperature.

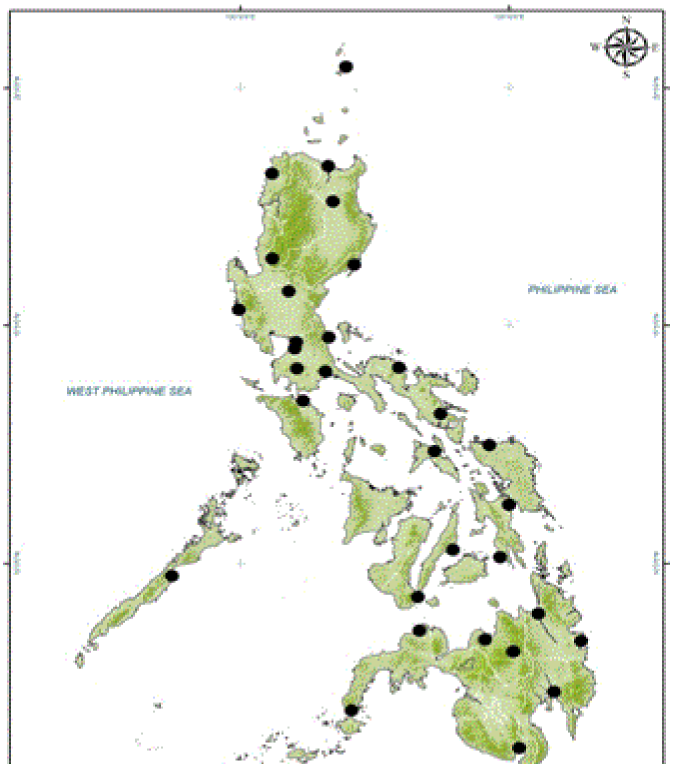
For further and easier discussion of climate projections, figures and graphs in the succeeding sections will use regional scale data notwithstanding that national and provincial scale are also available to project end-users. Model validation works are provided in the annexes.

Seasonal Temperature Change

Projected temperature change is based on mean temperature as a result of the average of maximum and minimum temperature from the GCMs. In general, all parts of the Philippines will experience increase in mean temperature under both A1B and A2 scenarios. Figure 8 shows the location of PAGASA stations used in the statistical downscaling of mean temperature projections.

Figure 9 compares the monthly average mean temperature of both ERA-Interim and GCMs 20C3M during the years 1979-1999 and results show that there is a highly significant correlation between ERA-Interim and 20C3M computed at R^2=0.99.

Under A1B scenario, it is expected that mean temperature will increase from 0.2-0.5°C while a projected increase of 0.1-0.6°C is estimated under A2 scenario (see Table 2). All scenarios suggest that there is no expected increase in mean temperature above 1°C until 2040. For both scenarios, the highest increase is expected in the months of March-April-May, which is the dry season in the Philippines, and lowest in the months of June-July-August, which coincides with wet season.



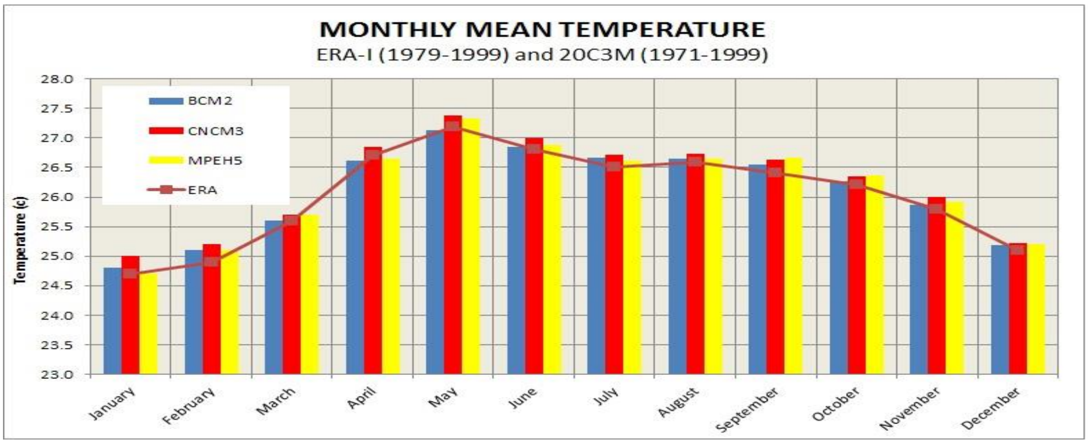


Figure 9. Monthly Mean Temperature of ERA-Interim (1979-1999) and 20C3M (1979-1999)

More interestingly, highest increase in mean temperatures are observed in highly urbanized regions like National Capital Region, Region 3, and Region 4-A, while lowest increase in Luzon are found in Cordillera Autonomous Region (see Figure 11 and Figure 12). This means that mountainous provinces in the Philippines that have typically less built-up areas tend to have lower increase in mean temperatures relative to provinces with highly urbanized areas and bigger population. All other increases in all seasons and in all parts of the country are consistent in both emission scenarios (see Table 2).

Table 2. Seasonal Changes in Mean Temperature (2011-2040)

Season	A1B Scenario	A2 Scenario
DJF	0.4-0.5°C	0.3-0.6°C
MAM	0.3-0.5°C	0.3-0.5°C
JJA	0.2-0.48°C	0.1-0.4°C
SON	0.3-0.5°C	0.3-0.4°C
ANNUAL	0.2-0.5°C	0.1-0.6°C

It also noteworthy that MPEH5 model produces negative values hence, a projected decrease in mean temperature in the months of September-October-November in Region 8, Region 11, and CARAGA. All of which are found in southeastern Philippines.

The annual mean temperature anomaly of each GCM and scenarios relative to baseline years was obtained. Figure 10 shows that it is only after 2030 that the temperature increase, showing a probable climate response, indicated at A1B and A2 scenarios to begin to diverge or separate.

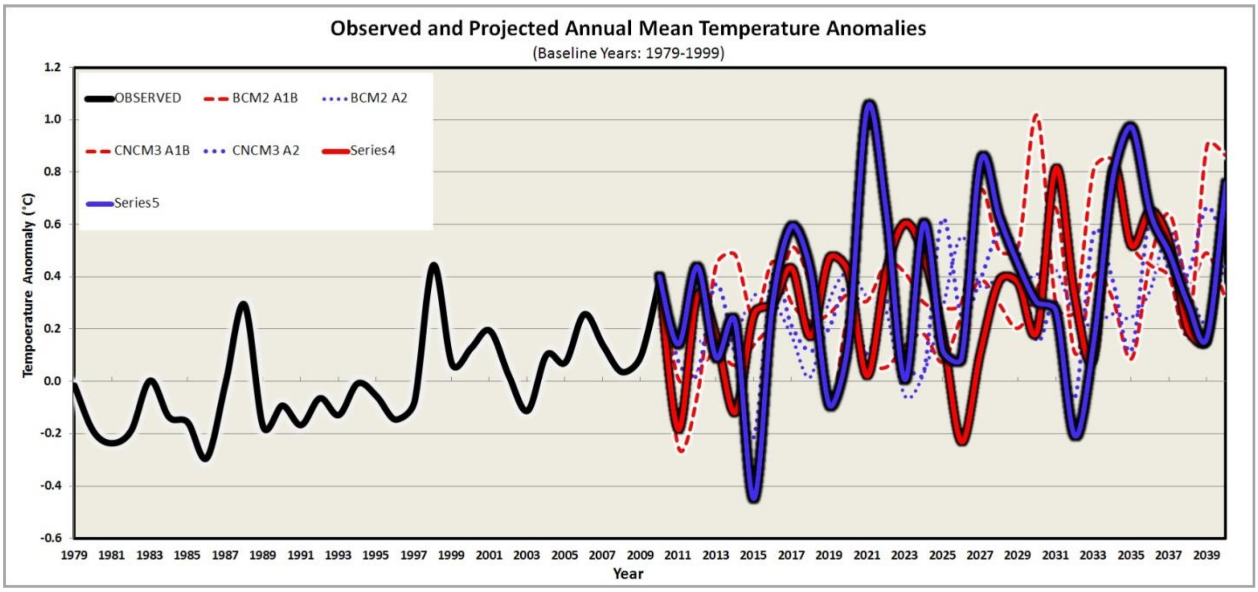


Figure 10. Observed and Projected Annual Mean Temperature Anomalies Relative to Baseline Years (1979-1999).

This could mean that GHGs already in the atmosphere have long lifetimes and will take at least 30 years for the atmosphere to stabilize. This is also observed in Figure 7 where there is an expected divergence between A1B and A2 scenarios in 2030-2035.

In summary the projected mean temperature for BCM2 registered the highest R-squared at 0.79 compared to CNCM3 and MPEH5 with R^2 = 0.77 and R^2= 0.76, respectively (refer to Table 3). This means that among the three models, BCM2 has the highest linear relationship with ERA-Interim in the baseline years(1979-1999) for mean temperatures.

Table 3. Comparative relationship between GCM-20C3M and ERA-Interim (1979-1999) Temperature.

GCM and ERA-Interim Temperature Dataset	R^2
BCM2-20C3M vs ERA-Interim	0.79

CNCM3-20C3M vs ERA-Interim	0.77
MPEH5-20C3m vs ERA-Interim	0.76

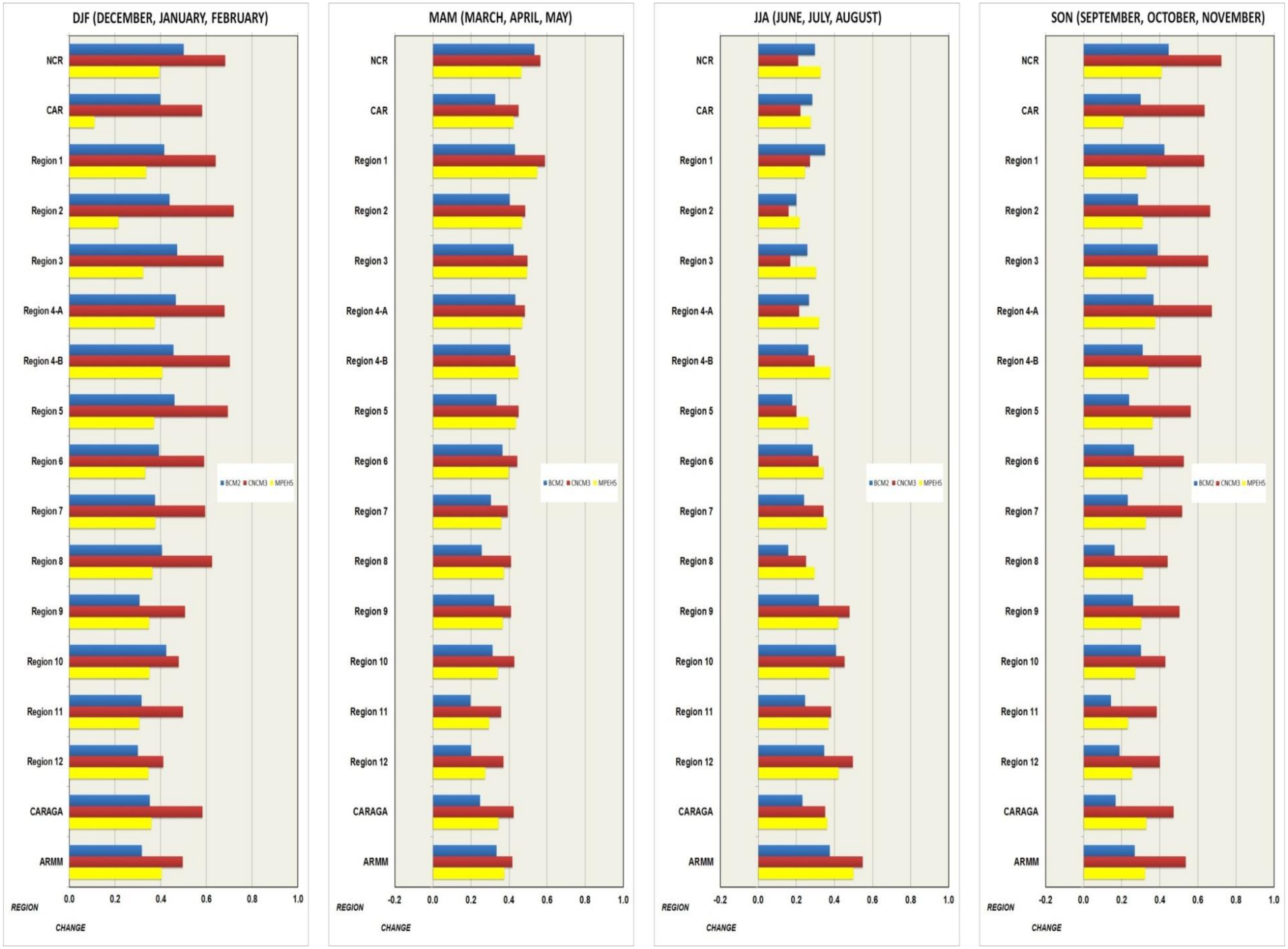


Figure 11. Seasonal Changes in Mean Temperature (°C) under A1B Scenario

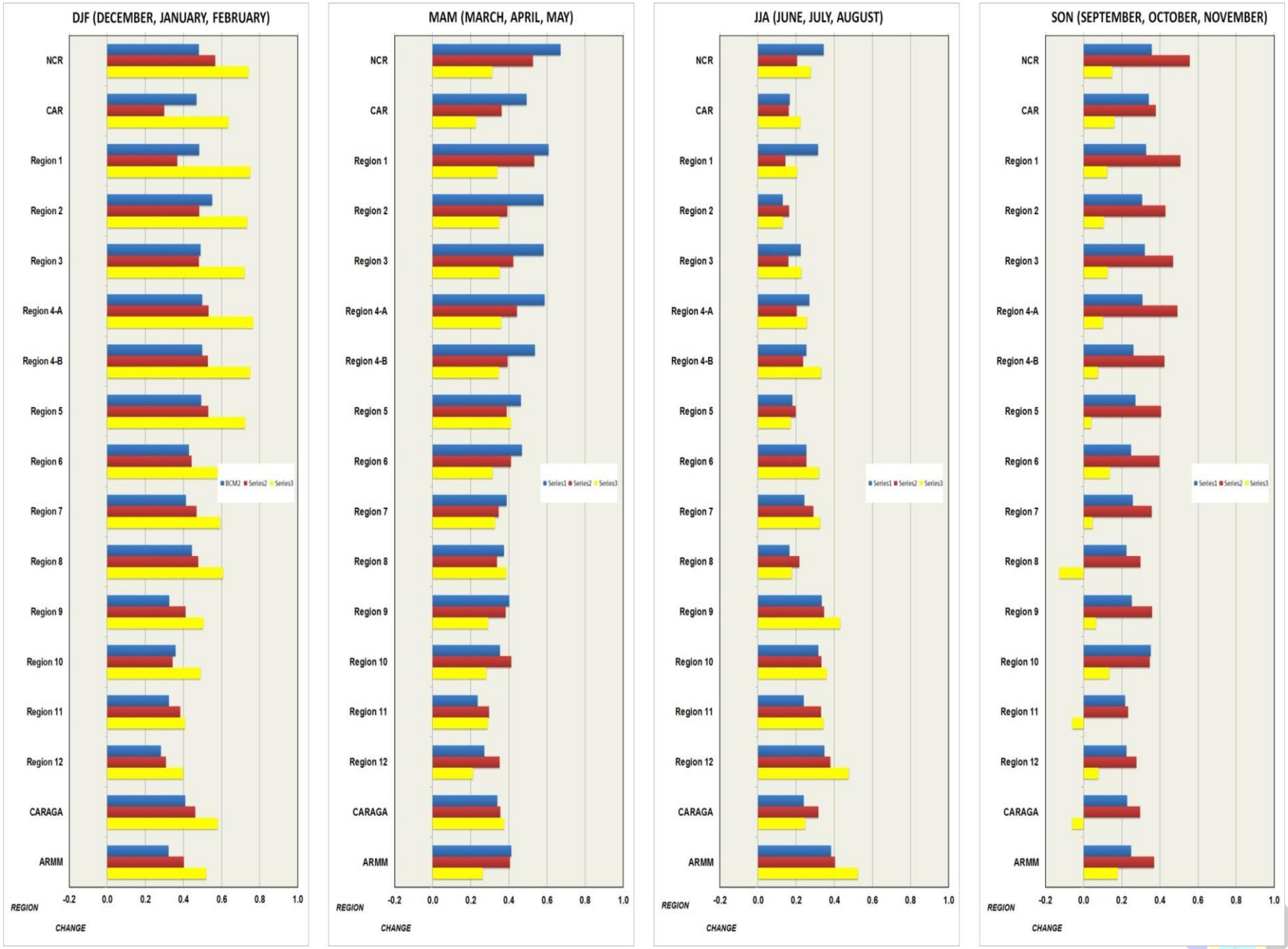


Figure 12. Seasonal Changes in Mean Temperature (°C) under A2 Scenario

Seasonal Rainfall Change

In an annual timescale, all parts of the country will experience increase in rainfall under both A1B (6-20%) and A2 (2.5-14%) scenarios (see Table 4). Highst rainfall increase is expected in CAR, Region 1, and Region 3, and it will be more pronounced in December-January-February.

Under A1B scenario, it is expected that seasonal rainfall will increase to as much as 41% and 35% under A2 scenario (see Table 4). Both scenarios suggest that there is no expected increase in seasonal rainfall greater than 50% until 2040.

Areas under Type 1 climate facing the western seaboard of the Philippines (see Figure 13) are characterized of having dry months from November to April and wet for the rest of the year. On the other side of the Philippines are areas characterized by Type 2 climate where the most pronounced rainfall is experienced from November to December. Figure 13 also shows the location of PAGASA Stations used in statistical downscaling of rainfall projections.

Based on Figure 15 and Figure 16, a decrease in rainfall will be experienced in the months of December-January-February in eastern Philippines (Region 8 and CARAGA). Both Region 8 and CARAGA fall under Type 2 climate. This suggests that these regions are projected to have less rainfall in the months where they should have more rainfall. Compared to the rest of the country, provinces in southeastern Mindanao have the lowest projected rainfall increase.

During March-April-May, BCM2 differs with CNCM3 and MPEH5 because it projects rainfall decrease under Type 2 climate. This suggests that Type 2 climate under BCM2 model; there are possible drier dry months under both emission scenarios. Negative values or rainfall decrease are also expected in NCR in MAM.

In June-July-August, decrease in rainfall are projected in Region 11 and Region 12 (see Figure 15 and Figure 16) where conditions are generally characterized by dry months from November to April and evenly distributed rainfall for the rest of the year. Other regions in Visayas and Mindanao have lower projected rainfall compared to Luzon. This translates to drier months in these areas.

There are varied projected seasonal changes in rainfall for the three GCMs. While this can be challenging to put together in a single analysis, there is a strong manifestation that the effect of monsoon will become more prominent especially in areas directly facing western and eastern seaboards of the Philippines in northwestern Luzon and southeastern Mindanao. Island provinces namely Batanes, Tawi-tawi, Camiguin, and Sulu have greater likelihood of more pronounced changes in monthly, seasonal, and annual rainfall.

Table 4. Seasonal Changes in Rainfall (2011-2040)

Season	A1B Scenario	A2 Scenario
DJF	-1.8-41.0%	-3.0-35.0%
MAM	8-23.0%	-2.5-17.0%
JJA	8.0-14.0%	-4.0-8.0%
SON	5.0-17.0%	4.0-17.0%
ANNUAL	6.0-20.0%	2.5-14.0%

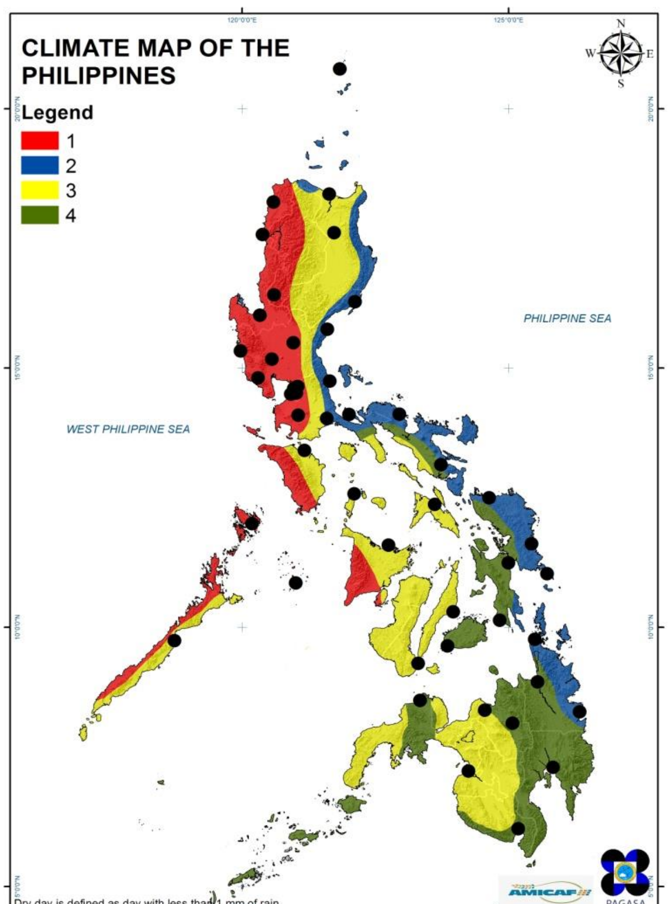
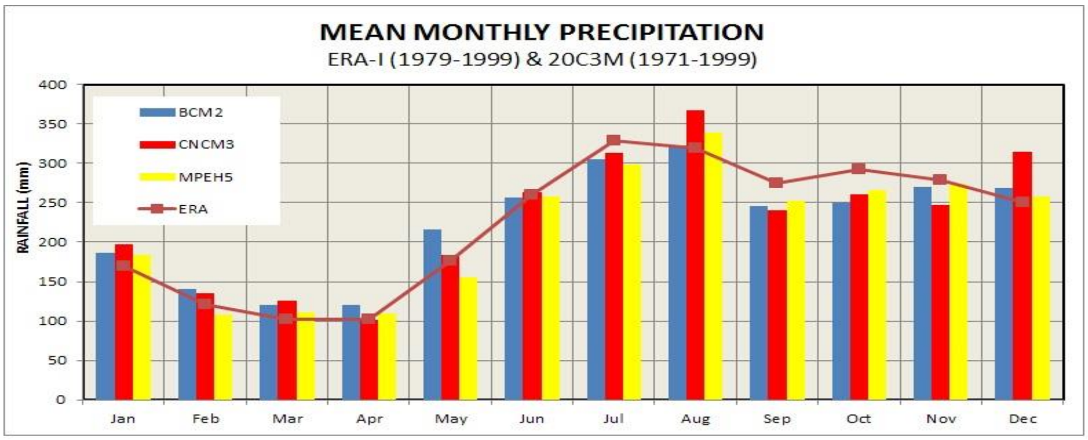


Figure 13. Climate Map of the Philippines and Location of PAGASA Stations used in Statistical Downscaling of Rainfall

Figure 14 compares the monthly mean rainfall of ERA-Interim and GCMs 20C3M in 1979-1999 and results show that the correlation between ERA-Interim and GCMs is computed at R^2=0.9. This also shows that the 20C3M of all GCMs, used to generate the climate projections, captures the monthly variability of previous observations.

In summary of projected rainfall, MPEH5 registered the highest R-squared at 0.44 compared with BCM2 and CNCM3 with R^2 = 0.32 and R^2= 0.28, respectively. This means that among the



three models, MPEH5 has the highest correlation with ERA-Interim during the baseline years (1979-1999).

Figure 14. Monthly Rainfall of ERA-Interim (1979-1999) and 20C3M (1979-1999)

Table 5. Comparative Relationship between GCM-20C3M and ERA-Interim (1979-1999) Rainfall

GCM and ERA-Interim Rainfall Dataset	R^2
BCM2-20C3M vs ERA-Interim	0.32
CNCM3-20C3M vs ERA-Interim	0.28
MPEH5-20C3M vs ERA-Interim	0.44

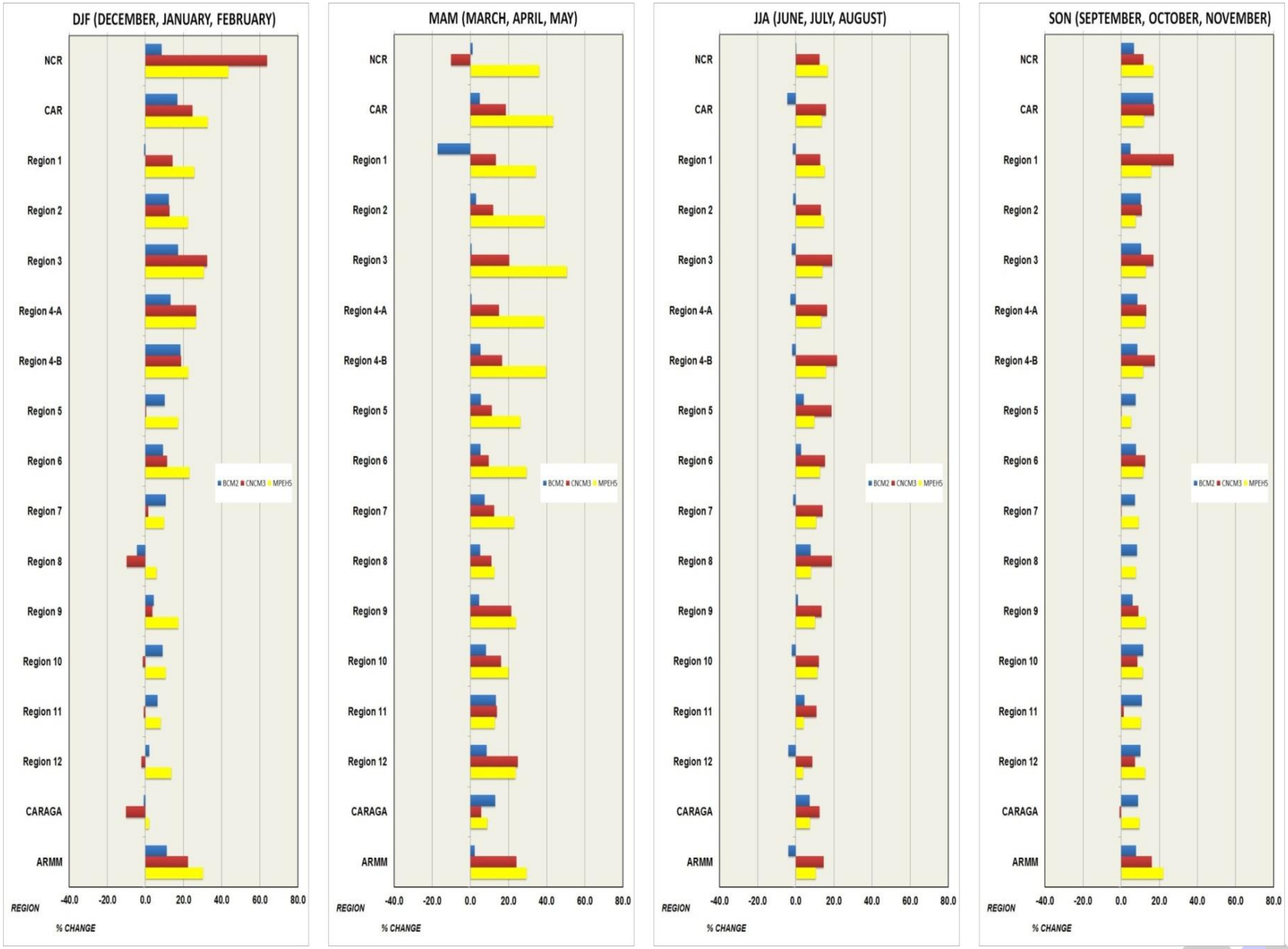


Figure 15. Seasonal Changes in Rainfall under A1B Scenario

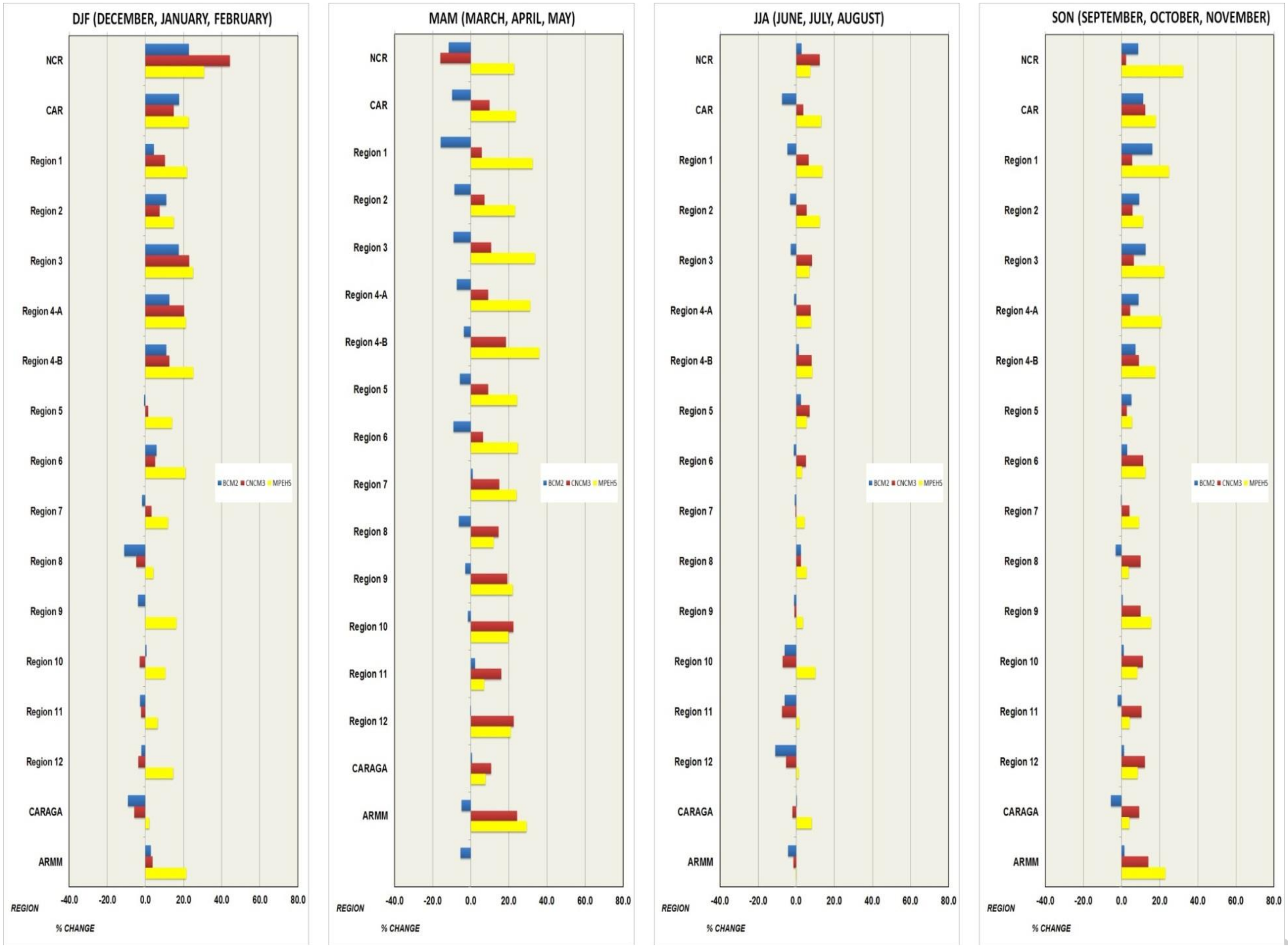


Figure 16. Seasonal Changes in Rainfall under A2 Scenario

Extreme Temperature Events

Extreme temperature events are defined as days with mean temperature greater than 36°C. Figure 17 suggest that there is an increase in the occurrence of extreme temperature events in Tuguegarao (Cagayan), General Santos (South Cotabato), and Science Garden (NCR) until 2040 (see Table 6).

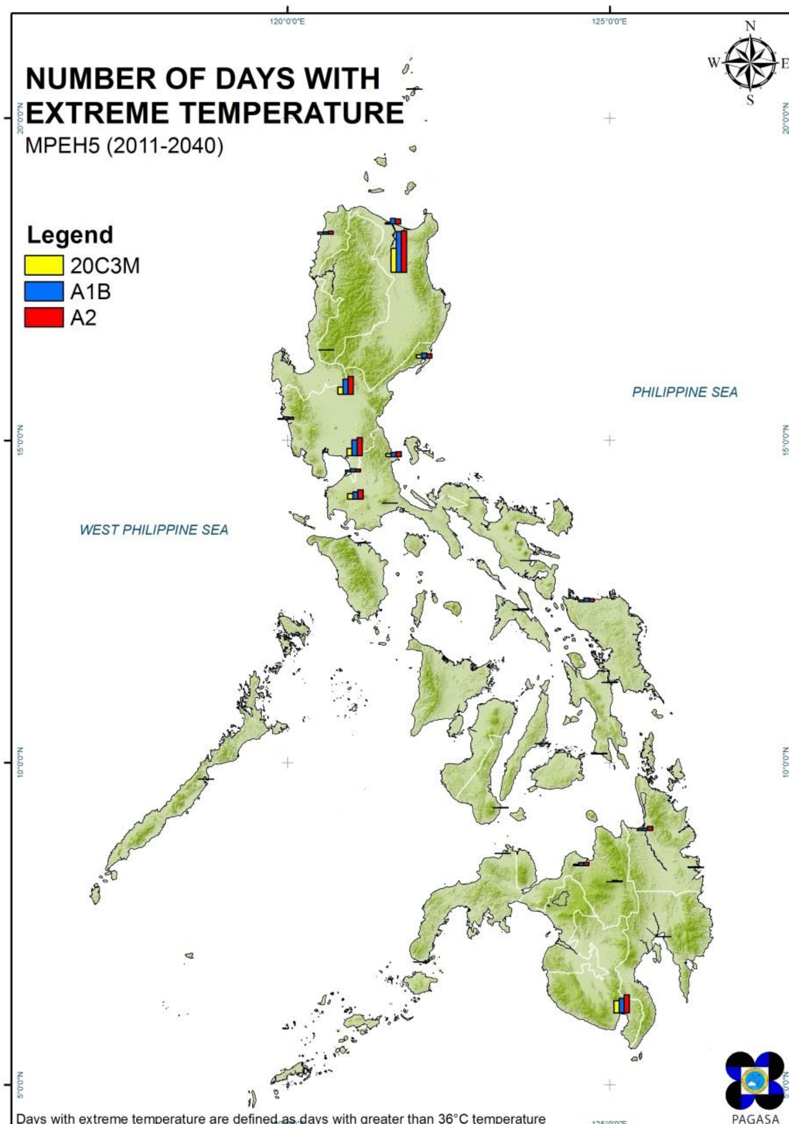


Figure 17. Number of Days with Maximum Temperature Exceeding 35°C under MPEH5 GCM

Table 6. Stations with Highest Number of Days with Extreme Temperature Exceeding 36°C

Number of Days with Extreme Temperature (2011-2040) and Corresponding Station using MPEH5				
RANK	*STATION*	*20C3M*	*A1B*	*A2*
10	**CATARMAN**	89	194	151
9	**BUTUAN**	91	125	210
8	**LAOAG CITY**	98	113	153
7	**INFANTA**	155	221	255
6	**CASIGURAN**	166	269	218
5	**AMBULONG**	289	382	494
4	**CLSU**	388	803	942
3	**SCIENCE GARDEN**	391	834	955
2	**GENERAL SANTOS**	636	763	957
1	**TUGUEGARAO**	1248	2146	2177

Extreme Number of Dry Days

Dry days are defined as 5-consecutive days with less < 1 mm of daily rainfall. Figure 18a shows that northern Luzon has the highest expected number of dry days from 2011-2040. Comparing this number of occurrences with baseline years (1979-2010), Figure 18b indicates that projected dry days will be more frequent in Laoag City (Ilocos Norte), Vigan City (Ilocos Sur), and General Santos (South Cotabato) under both scenarios. In general, all parts of the country will have more number of dry days (see Table 7)

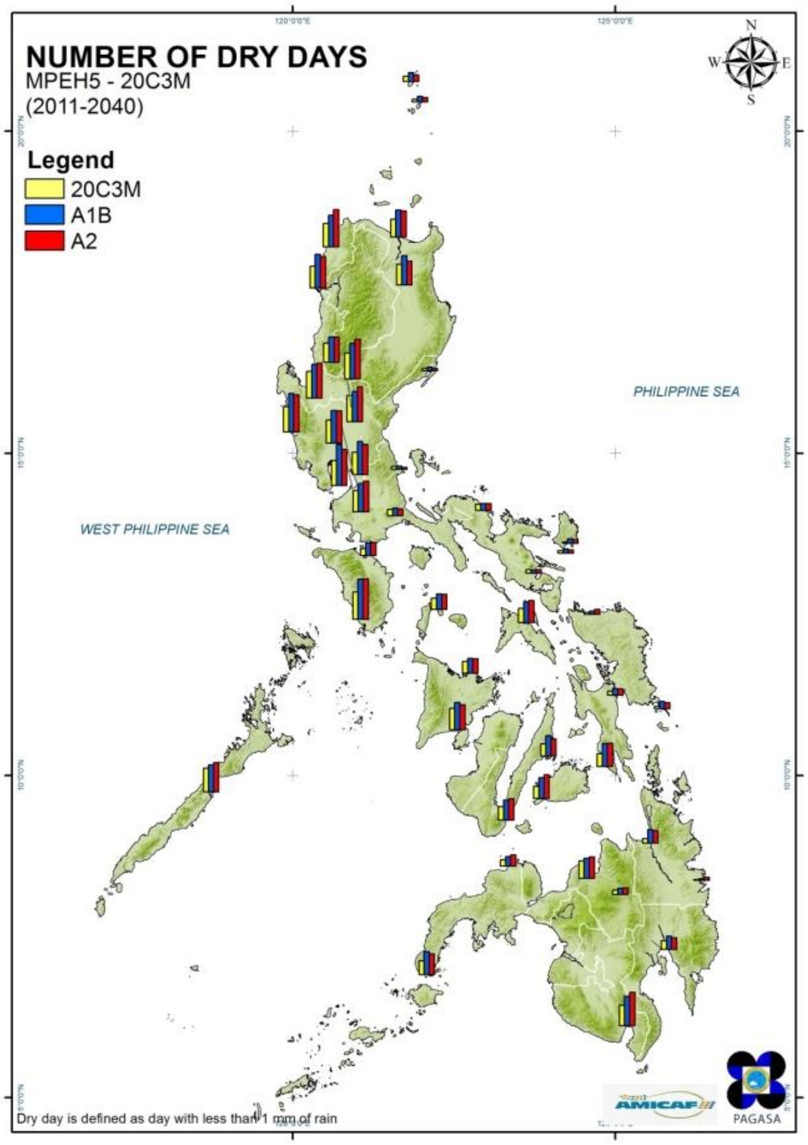


Figure 18. Number of Dry Days (5-consecutive days with <1 mm of daily rainfall) under MPEH5 GCM

Table 7. Stations with Highest Number of Dry Days

Number of Dry Days* (2011-2040) and Corresponding Station using MPEH5				
RANK	*STATION*	*20C3M*	*A1B*	*A2*
10	**SCIENCE GARDEN**	93	139	127
9	**PORT AREA (MCO)**	97	137	136
8	**LAOAG CITY**	99	133	157
7	**PUERTO PRINCESA**	100	114	123
6	**SANGLEY POINT**	105	173	152
5	**IBA**	107	162	156
4	**CLSU**	109	149	167
3	**CABANATUAN**	111	127	147
2	**DAGUPAN CITY**	112	141	147
1	**SAN JOSE**	115	169	171

*Dry days are events defined as 5 consecutive days with <1mm of daily rainfall with each occurrence counted as one event

Extreme Daily Rainfall

Extreme daily rainfall is defined as a day with greater than or equal to 100 mm of rainfall. Figure 19 shows the areas with highest number of projected extreme daily rainfall. These include Hinatuan (Surigao del Sur), Casiguran (Aurora), and Iba (Zambales) (see Table 8).

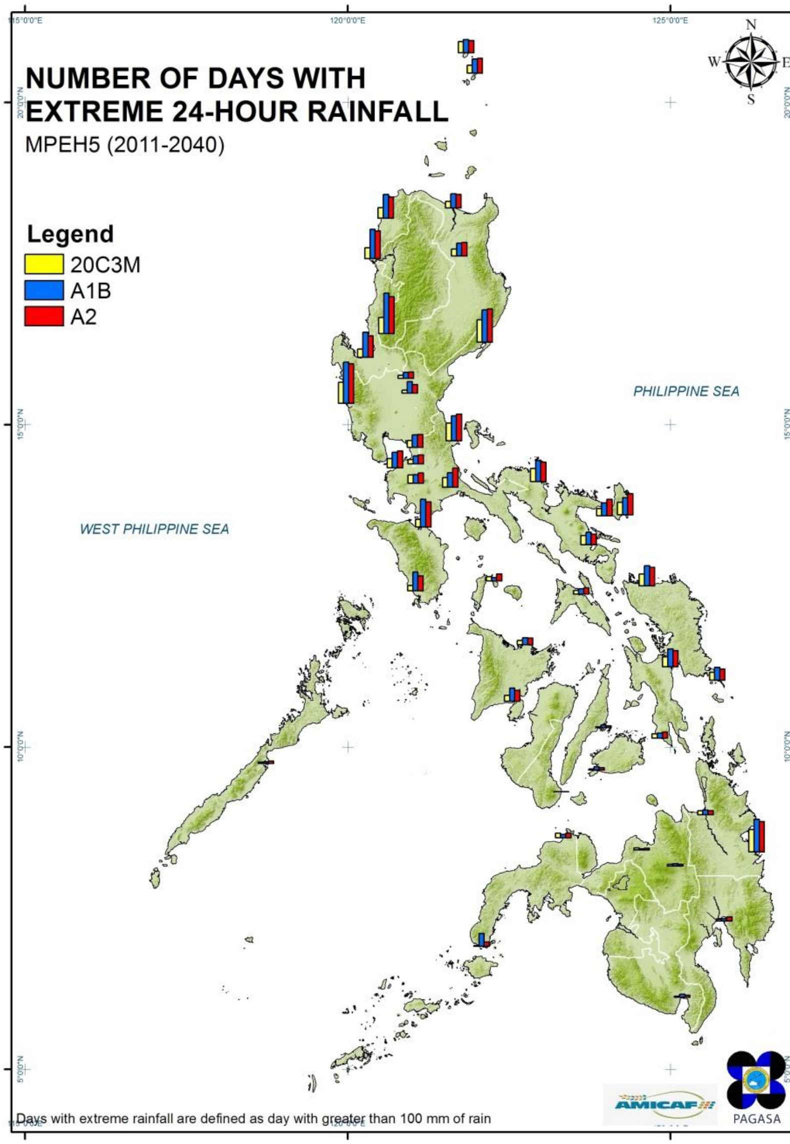


Figure 19. Number of Days with Extreme Daily Rainfall exceeding >= 100 mm of daily rainfall under MPEH5 GCM

Table 8. Stations with Highest Number of Days with Extreme 24-hour Rainfall > 100 mm

Number of Days with Extreme 24-hour Rainfall (2011-2040) and Corresponding Station using MPEH5			
STATION	*20C3M*	*A1B*	*A2*
VIGAN	94	250	236
ITBAYAT	96	115	106
CATARMAN	101	171	157
VIRAC RADAR	107	146	180
DAET	114	181	169
BAGUIO	140	347	317
INFANTA	151	213	228
IBA	182	353	338
CASIGURAN	190	277	285
HINATUAN	193	281	260
*Extreme daily rainfall are events defined as days with >100 mm of rainfall with each occurrence counted as one event			

Conclusions

This exercise proved to be extremely useful as a multi-disciplinary approach to assess the impact of climate change to food insecurity in household level. In PAGASA point of view, the tasks required to complete the needed output were done just in time and with much fulfillment.

Results obtained out of this project showed that there will be significant climate changes in coming years. There are indications of increasing frequency of extremes events both in number of occurrence of 24 hour extreme rainfall and number of dry days which may likely happen.

The spatial aggregation of both rainfall and temperature to provincial level is one of the best achievements this project was able to deliver. It showed that there are places which may not experience increase in temperature or rainfall or both, which in our point of view, may have logical and scientific basis. Furthermore, the method of data processing of incorporating considerations of topographical features of the Philippines using Analyse Utilisant le RElief pour l'Hydrométéorologie (AURELHY), made a very distinct difference. Visualization of the interpolated values allowed us to see the effects of topographical aspects of surfaces of bigger land masses in main islands of the country. Changes in temperature patterns with varying elevations made us consider mountains and valleys as far as the pixel resolutions may permit us.

The issue in which model maybe applicable for planning in climate change adaptation purposes should be guided by the validation results obtained in the experiments. Readers and users of this report should consider that nobody in this wide world will be able to know exactly what will happen in the future using computer models. We could only make an educated estimate based on current technologies available. Perhaps it will be useful for users and readers of this report to look at how the model performed to simulate past events or the validation part of the exercise. One should make a serious note on model skill or the measure of relationship between model outputs trained to simulate the past against the observed values. Model skill tells us how close the model simulates the reality, the higher the relationship in terms of R^2 the better the skill is. There are other ways in measuring model skill but note that this exercise is limited to the linearity of the relationship between model outputs against the observed values as mentioned

earlier.

In conclusion, generally all three models showed similar linearity to the observed values although MPEH5 showed very promising results both in temperature and rainfall parameters. Please note that the model MPEH5 did not top in all the tests performed. Results showed that all three models have very high measure of linearity with respect to temperature (refer to Table 3), but it showed best among two other models in terms of rainfall (refer to Table 5).

Recommendations

The results can now be utilized for all interested parties specially our partner institutions who would like to dig deeper in their respective areas of interest. In PAGASA point of view, more work are needed to be done, we conclude that we need more time to perform other useful analysis like onset of rainy season, length of wet season and other important climate events that will affect our future socio-economic conditions.

We noted significant growth with our project cooperation among institutions and computing facilities are nowadays better than before. Consider that PAGASA are now more capable both in terms of human resources and technical tools. We were made aware of available funds to cover work for more scenario analysis from data files obtained from the past experiments and similar work to be covered on CMIP5. We are sure that there will be more exciting and useful activities to be made and joined by our partner institutions in the future.

Finally, our technical staff learned a lot with this exercise, it provided us with wider and better perspective and understanding in various aspects of climate change impact scenarios. There were lots of challenges we encountered during the project implementations, there were times when we felt that we were pushed to our breaking points. We thanked God above all, it was his divine will that made us faced and encountered these events; it was also his guiding hands that carried us all along which perhaps made us all more stronger and better persons.

Acknowledgement

We would like to convey our sincerest thanks to all specially the local FAO-AMICAF staff that were very nice to extend their assistance and their caring concerns for us, unwavering in their commitments and most of all their professionalism which made us all inspired and comfortable while working with them. Heart full thanks to Hideki and Tatsu our Japanese mentors for all their devotions to make this project a success same with the technical staff in the University of Cantabria specially Dr. Jose Manuel Gutierrez who was very nice and unselfish accommodating person, and his technical staff Rodrigo Manzanas who has many sleepless nights during our stay in the University of Cantabria. God bless you all….

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ANNEXES

ANNEX A

Comparison of Projected Rainfall and Changes

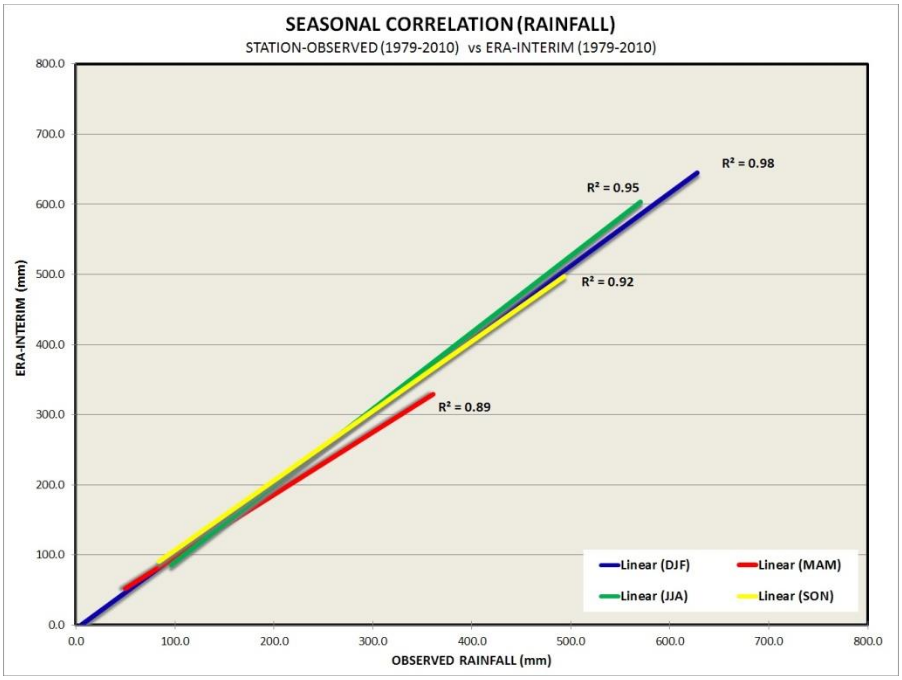


Figure A-1. Comparison of Seasonal Rainfall from PAGASA Observations (1979-2010) versus ERA-INTERIM (1979-2010)

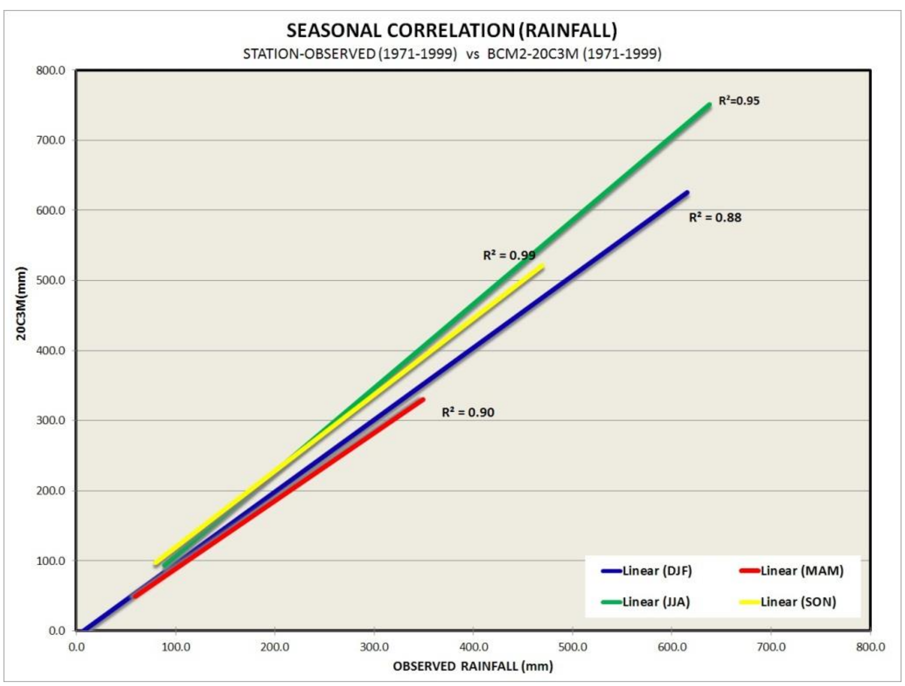


Figure A-2. Comparison of Seasonal Rainfall from PAGASA Observations (1979-1999) versus BCM2-20C3M (1971-1999)

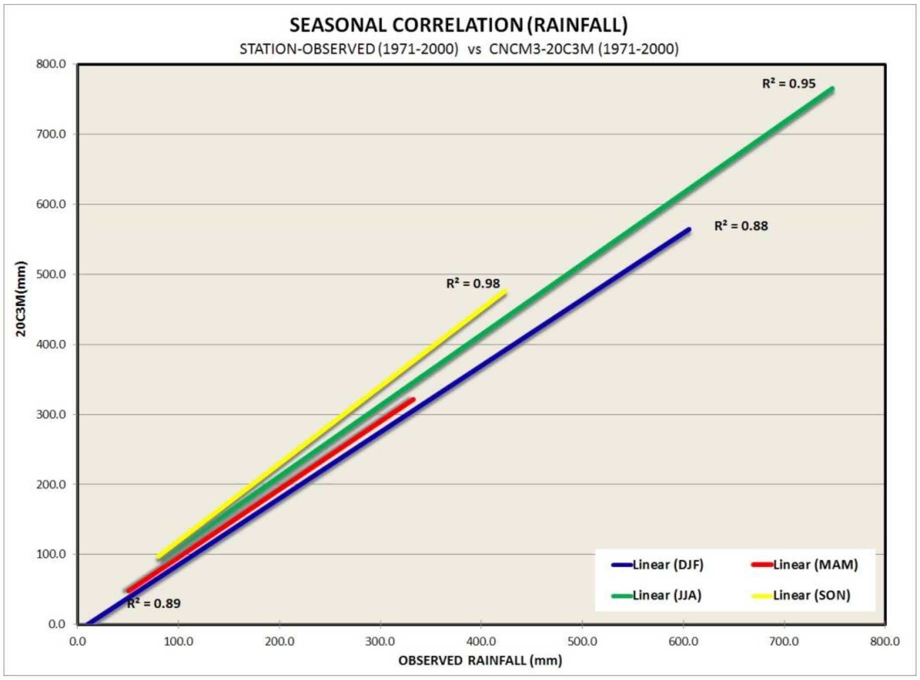


Figure A-3. Comparison of Seasonal Rainfall from PAGASA Observations (1979-2000) versus CNCM3-20C3M (1971-2000)

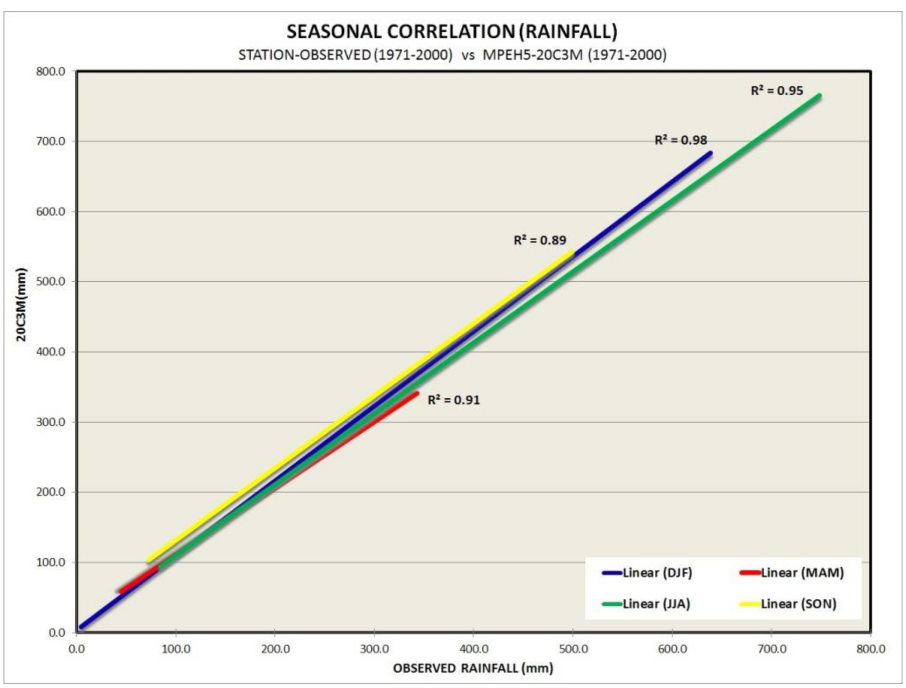


Figure A-4. Comparison of Seasonal Rainfall from PAGASA Observations (1979-2000) versus MPEH5-20C3M (1971-2000)

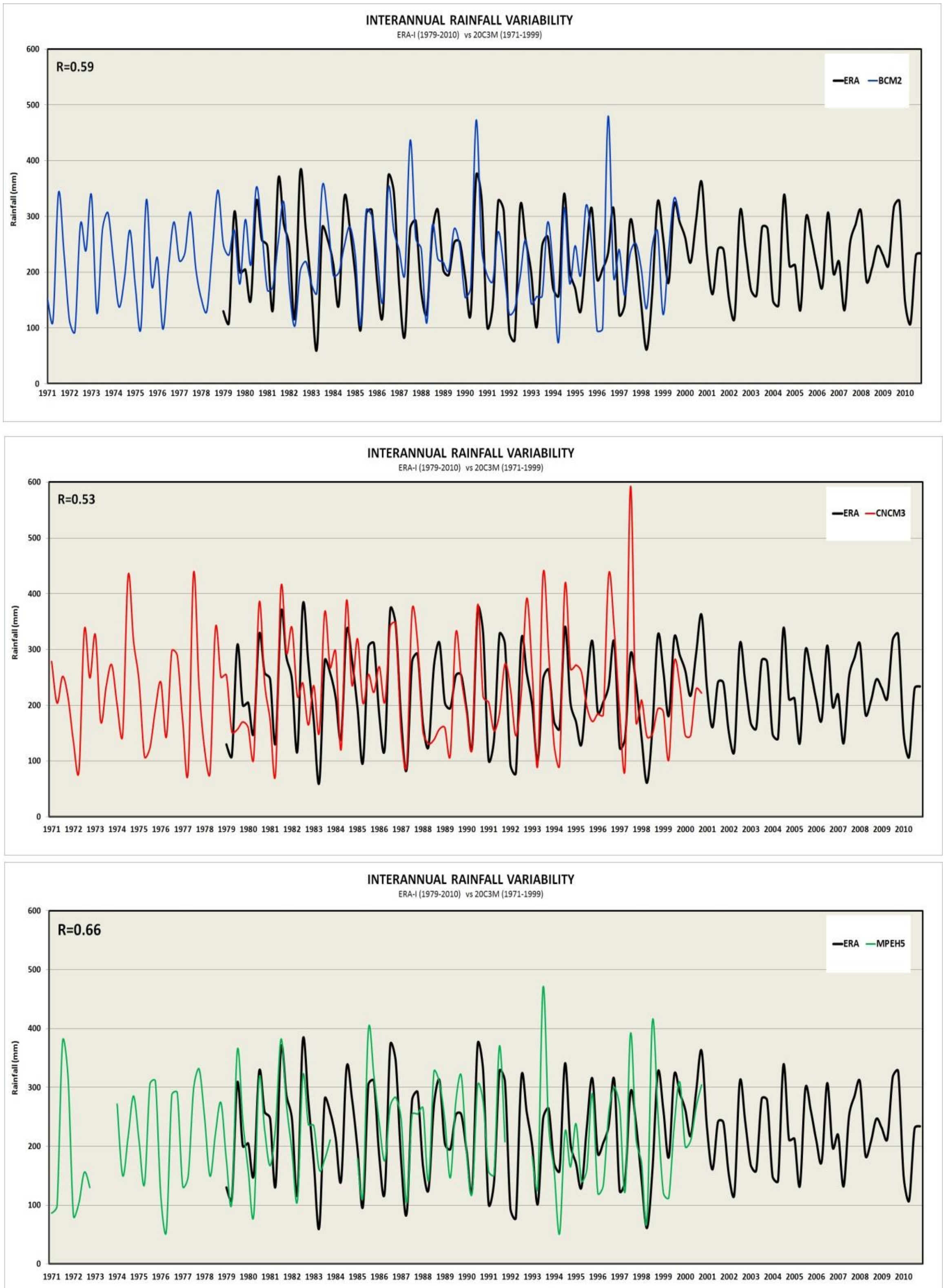
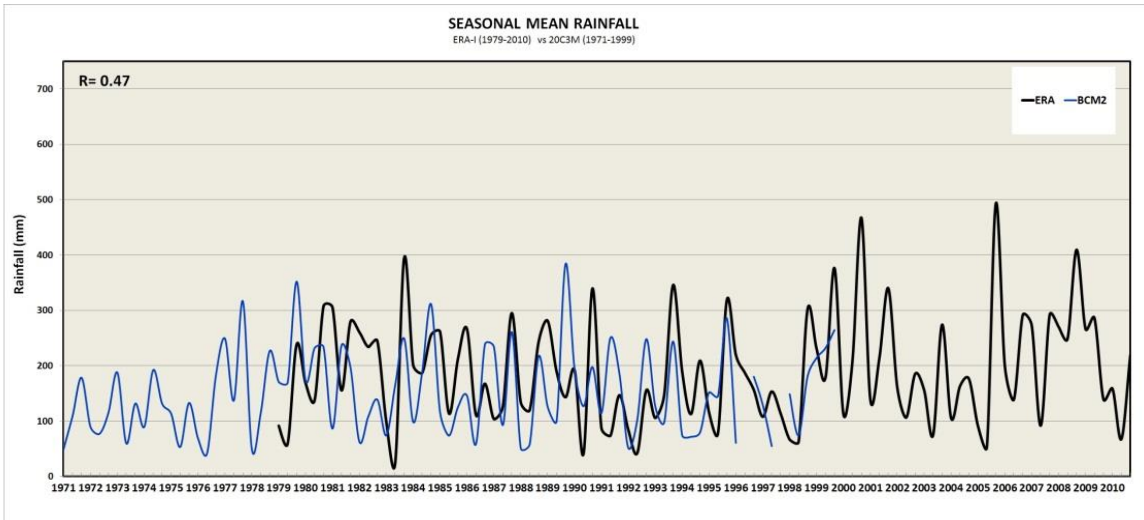
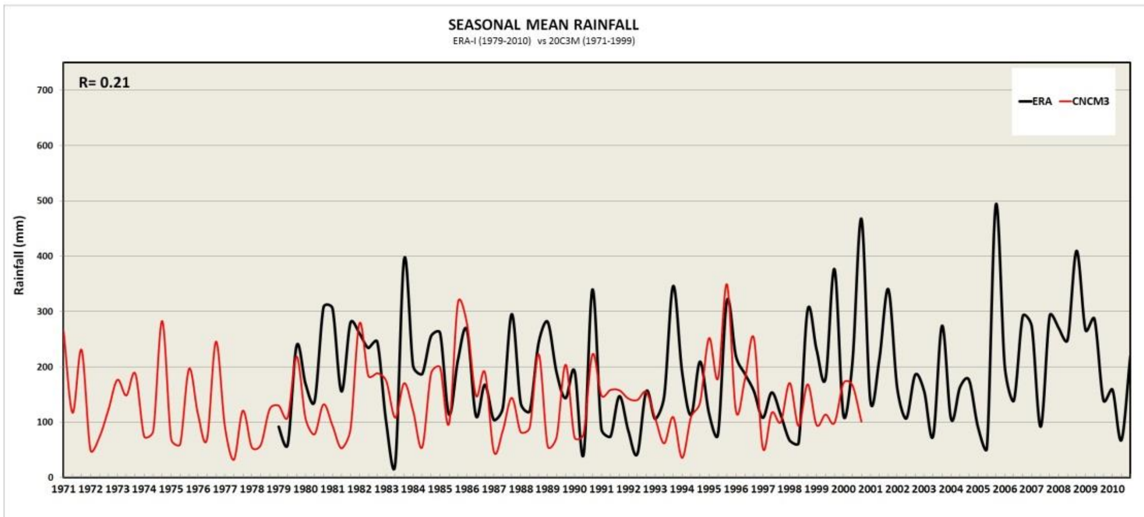


Figure A-5. Interannual Rainfall Variability comparing ERA-INTERIM (1979-2010) and BCM2-20C3M (*Figure A-5.a*), CNCM3-20C3M (*Figure A-5.b*), and MPEH5-20C3M (*Figure A-5.c*)





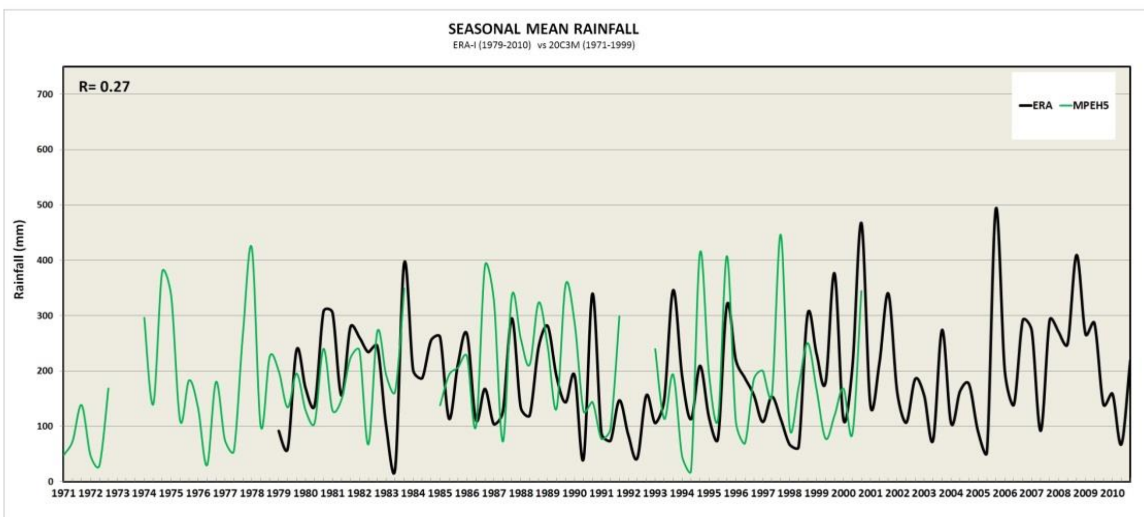


Figure A-6. Seasonal (**March-April-May**) Mean Rainfall comparing ERA-INTERIM (1979-2010) and BCM2-20C3M (*Figure A-6.a*), CNCM3-20C3M (*Figure A-6.b*), and MPEH5-20C3M (*Figure A-6.c)*

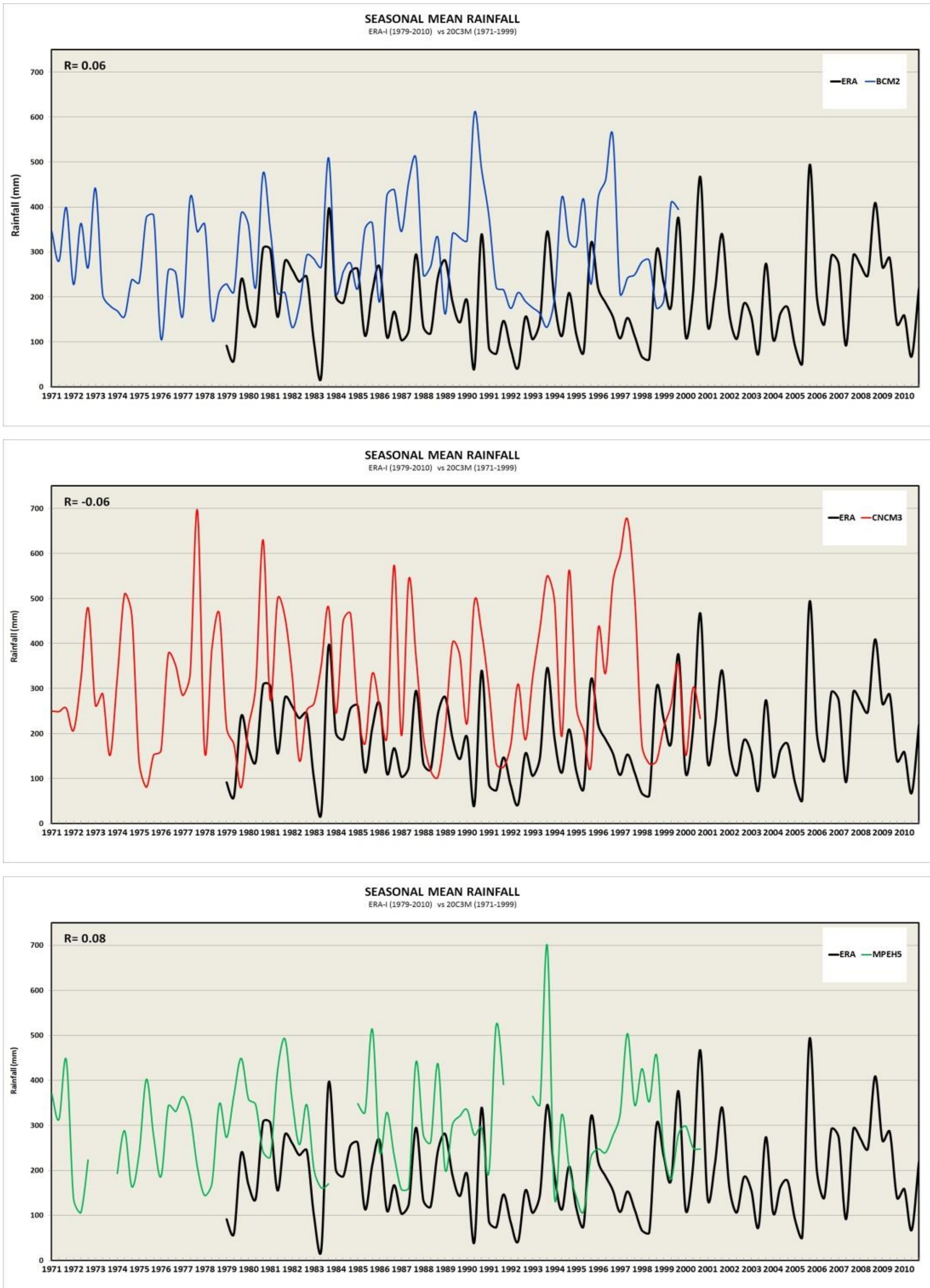


Figure A-7. Seasonal (**June-July-August**) Mean Rainfall comparing ERA-INTERIM (1979-2010) and BCM2-20C3M (*Figure A-7.a*), CNCM3-20C3M (*Figure A-7.b*), and MPEH5-20C3M (*Figure A-7.c)*

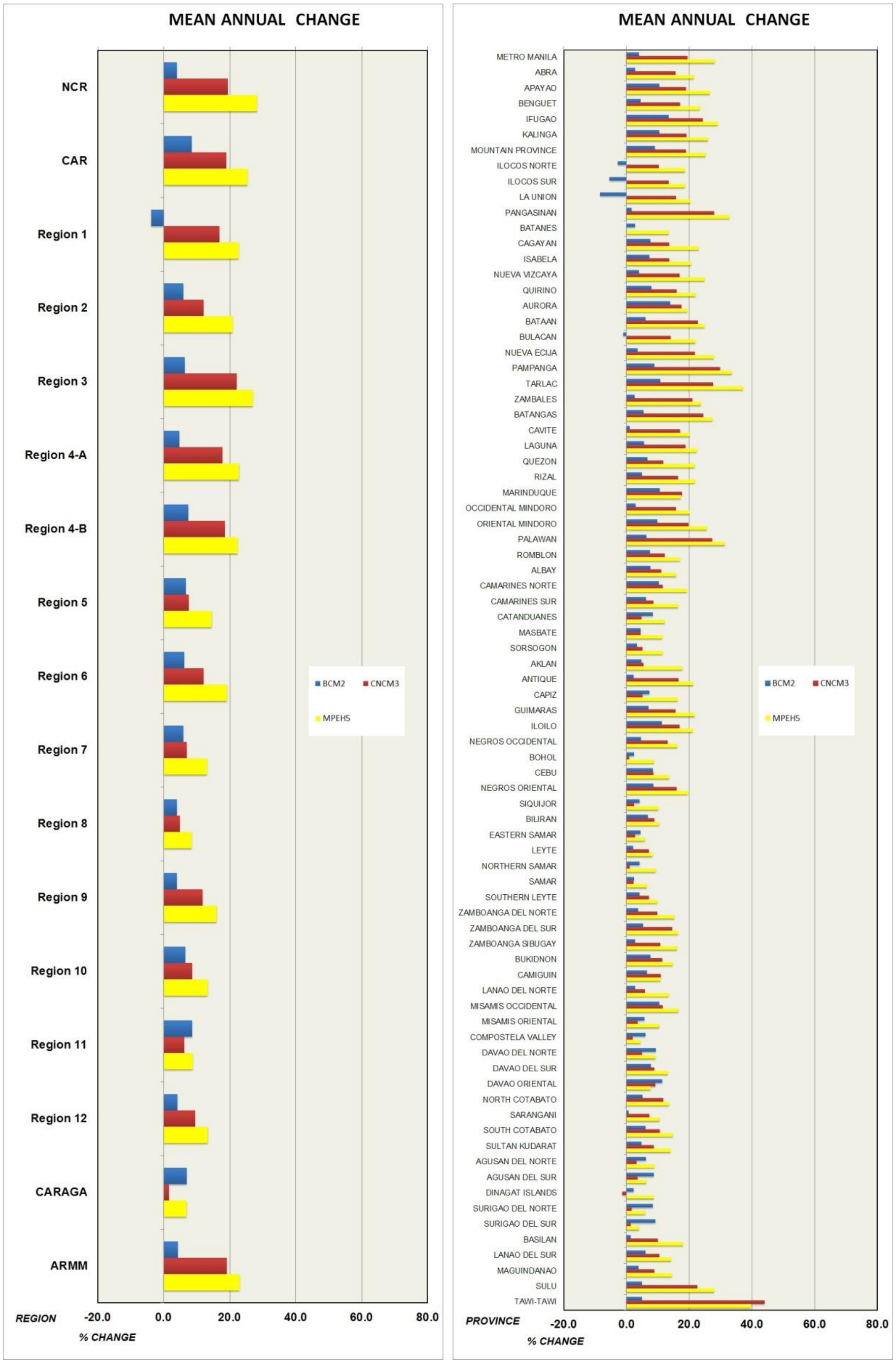


Figure A-8. Mean Annual Rainfall Change under A1B Scenario using the average of three GCMs

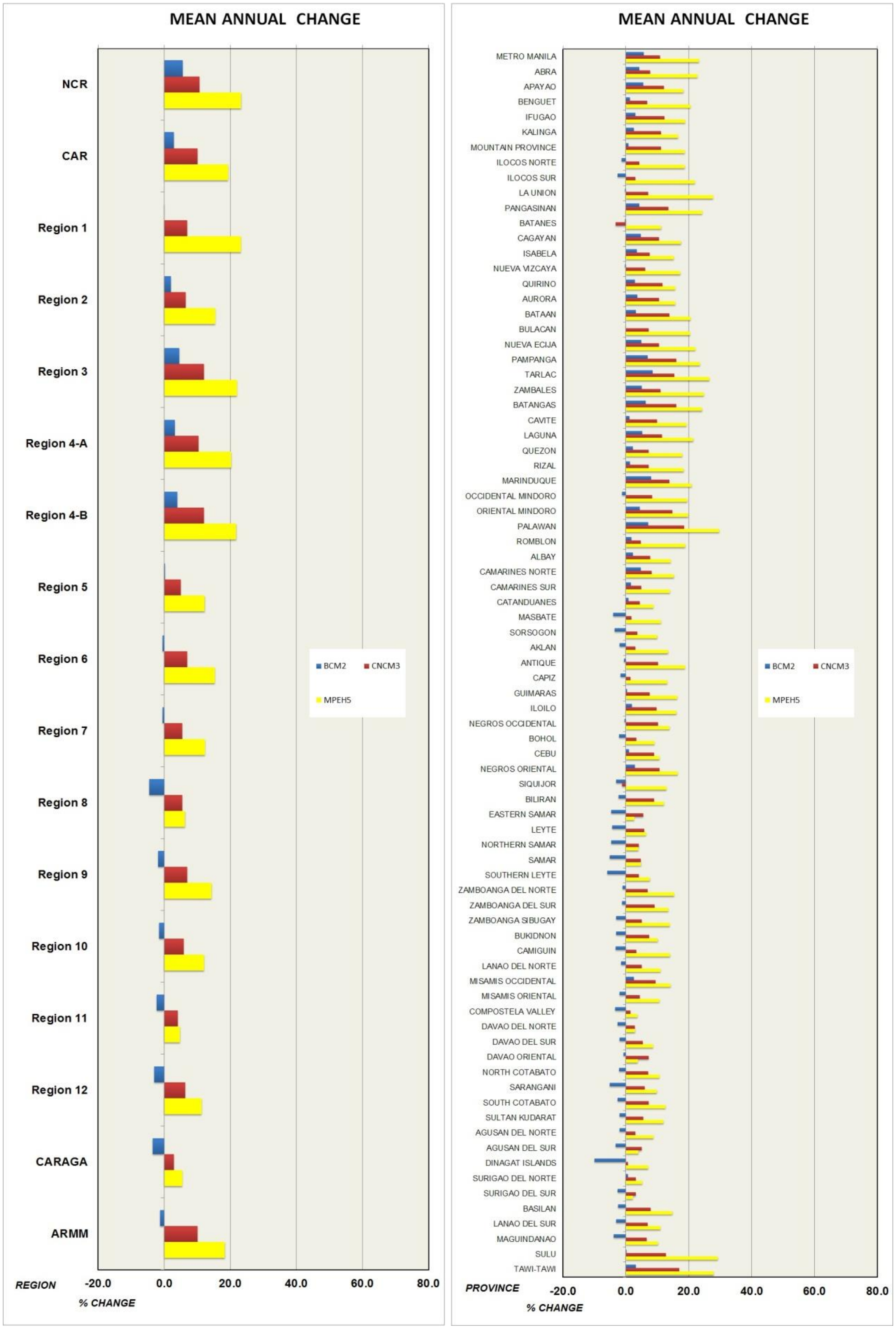


Figure A-9. Mean Annual Rainfall Change under A2 Scenario using the average of three GCMs

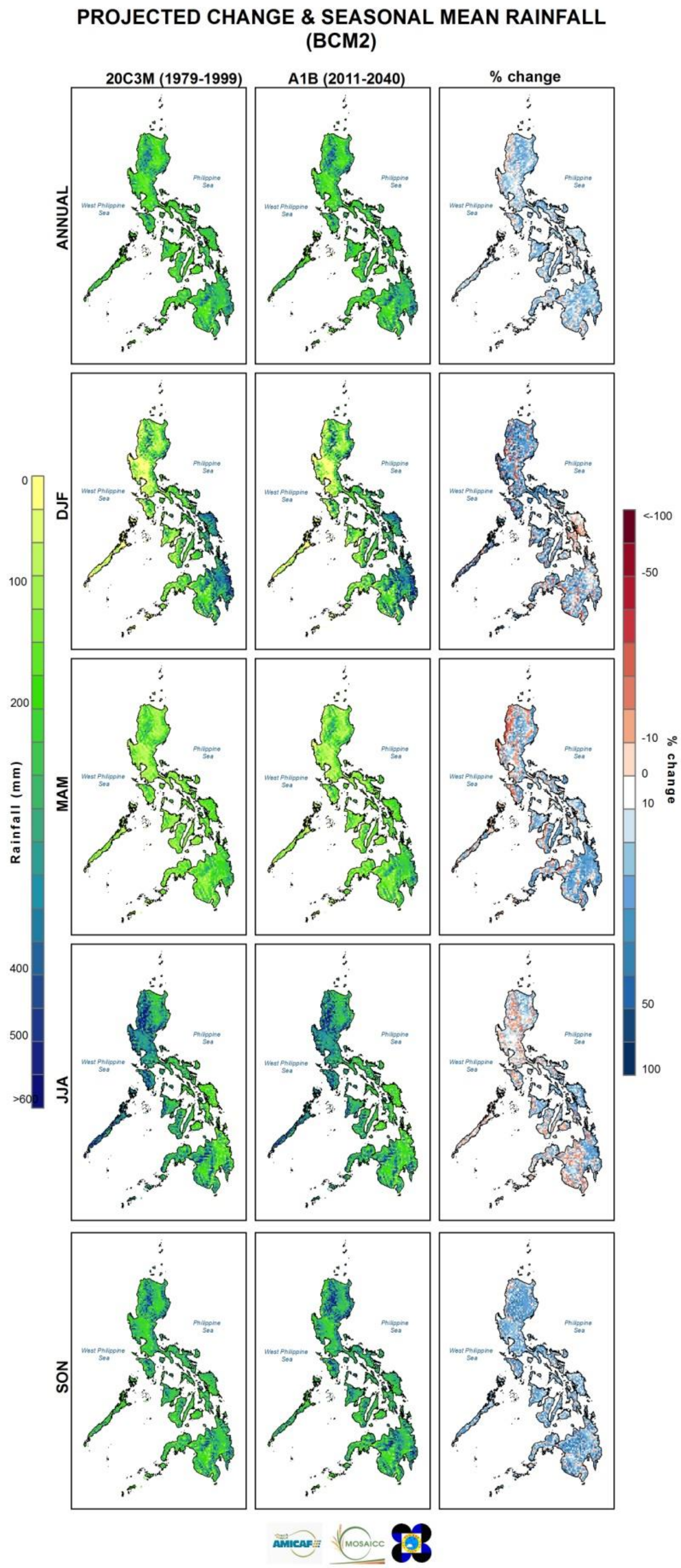

PROJECTED CHANGE & SEASONAL MEAN RAINFALL
(BCM2)
20C3M (1979-1999)
A1B (2011-2040)
% change
ANNUAL
DJF
MAM
JJA
SON
Philippine Sea
West Philippine Sea
Rainfall (mm)
0
100
200
400
500
>600
% change
<-100
-50
-10
0
10
50
100
AMICAF
MOSAICC

Figure A-10. Projected Seasonal Rainfall & Change under A1B Scenario using BCM2

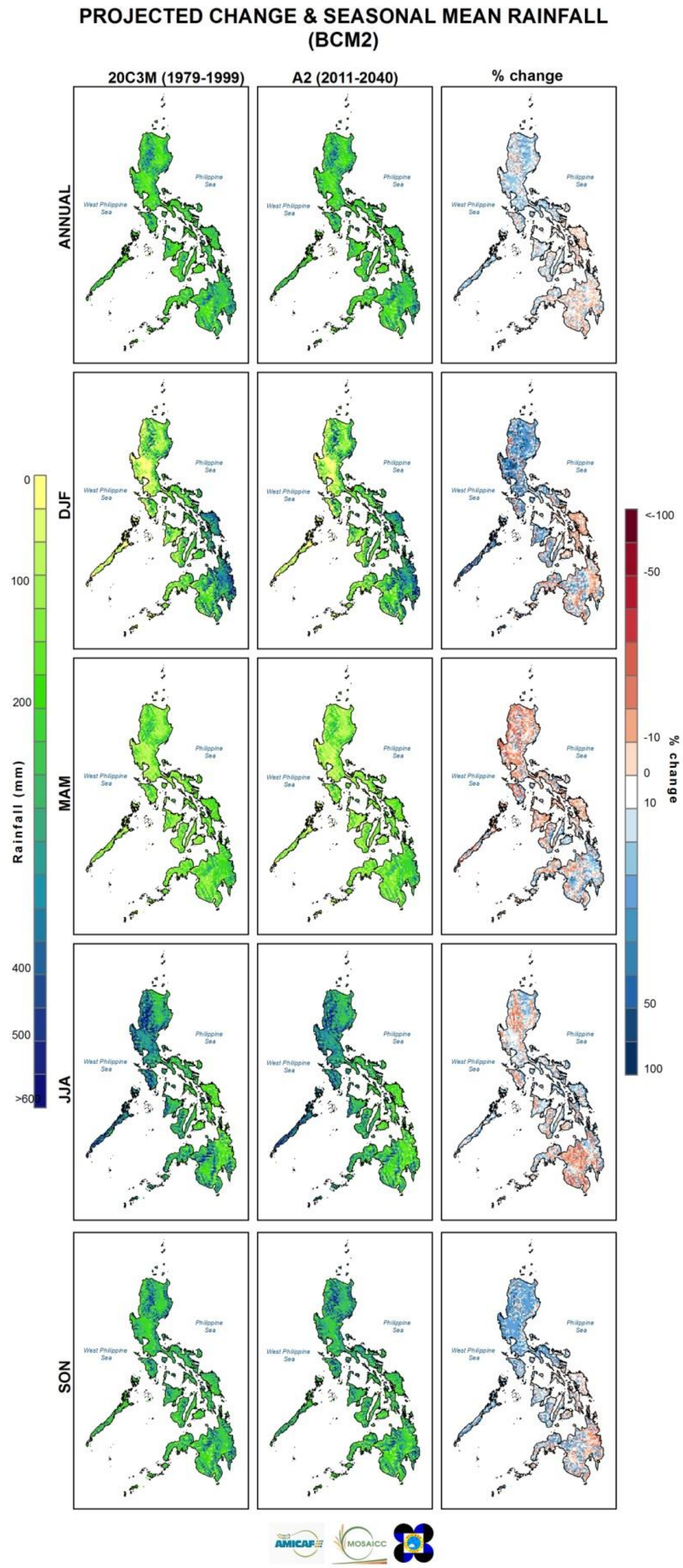


Figure A-1 using BCM2

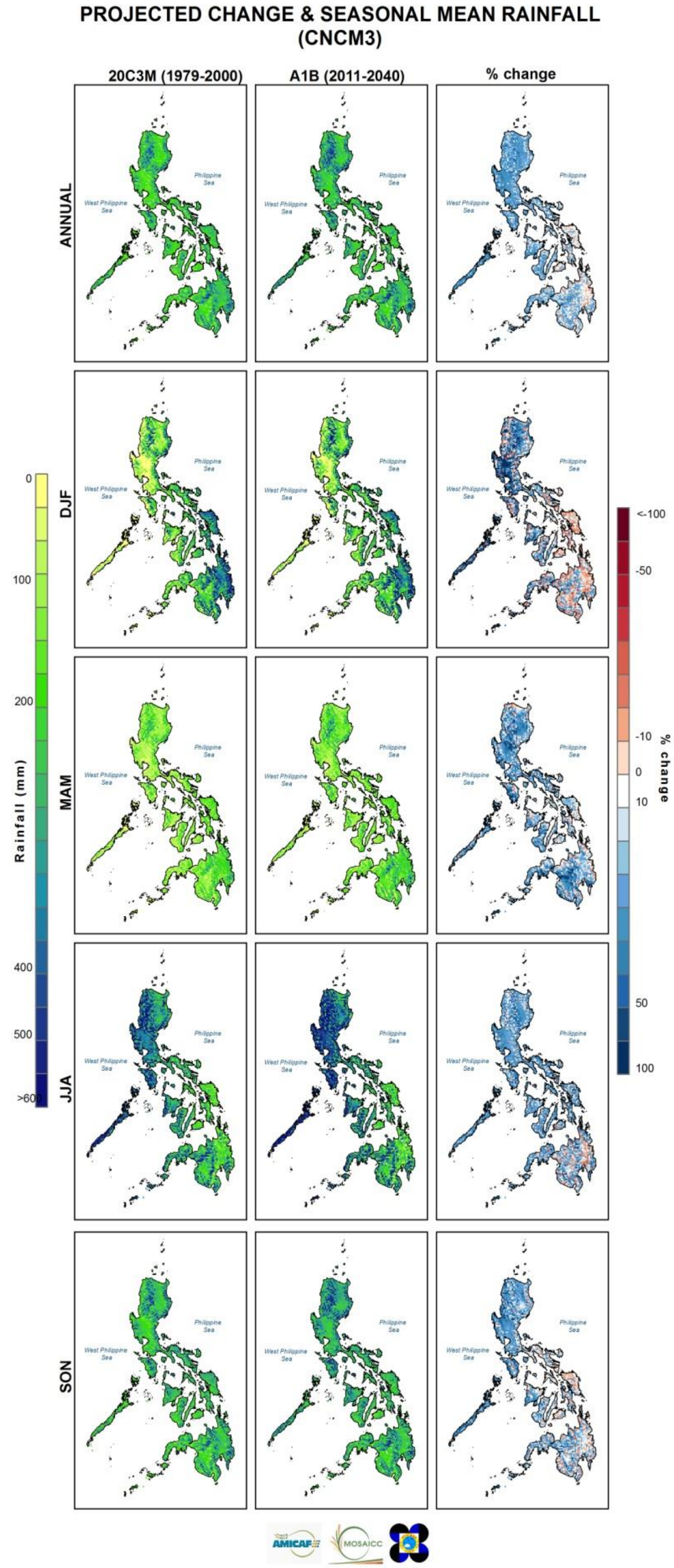


Figure A-12. Projected Seasonal Rainfall & Change under A1B Scenario using CNCM3

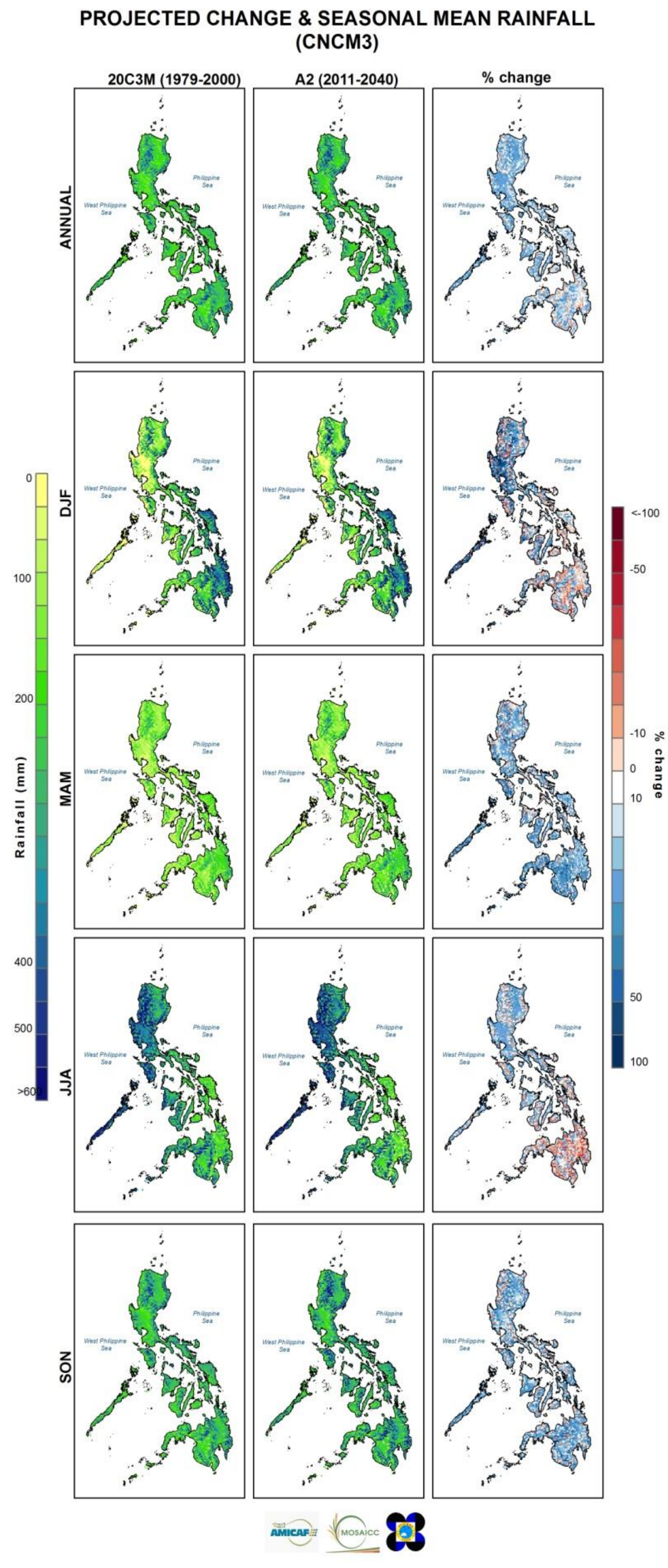


Figure A-13. Projected Seasonal Rainfall & Change under A2 Scenario using CNCM3

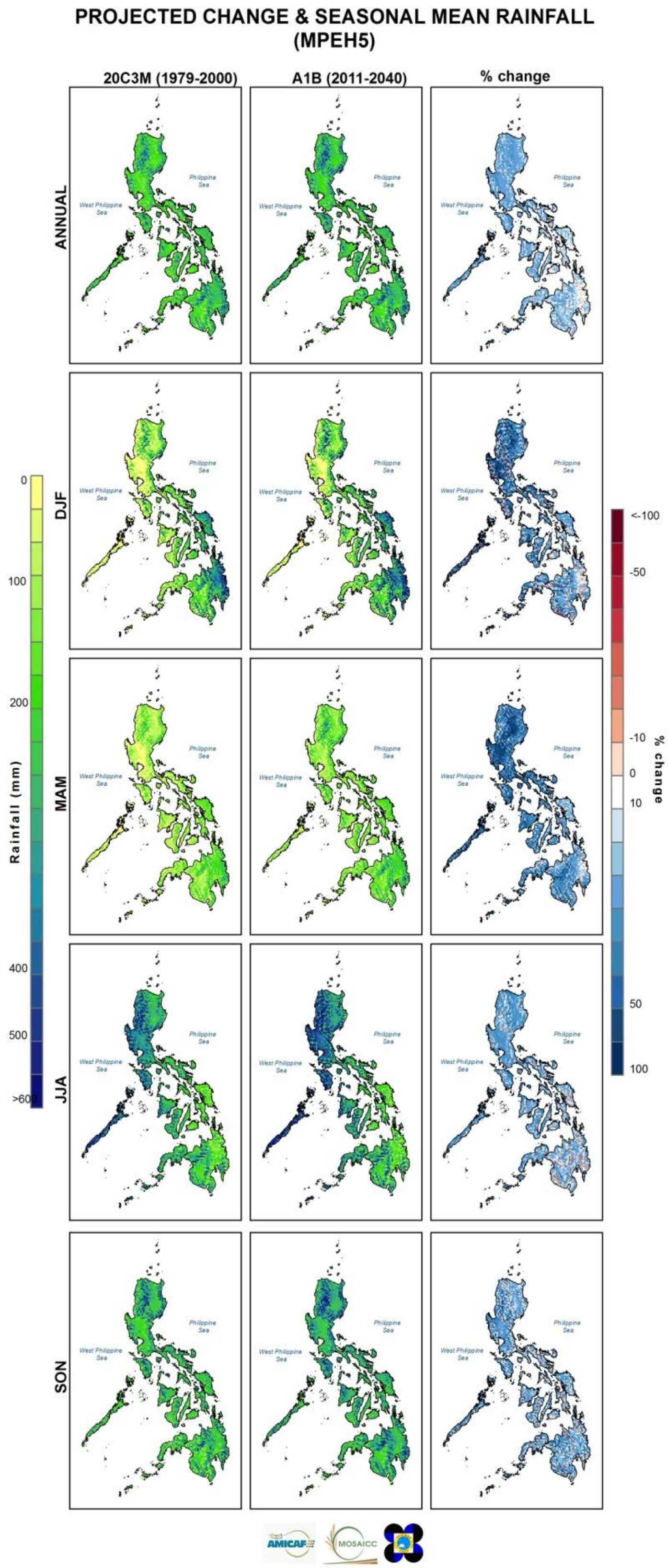


Figure A-14. Pro MPEH5

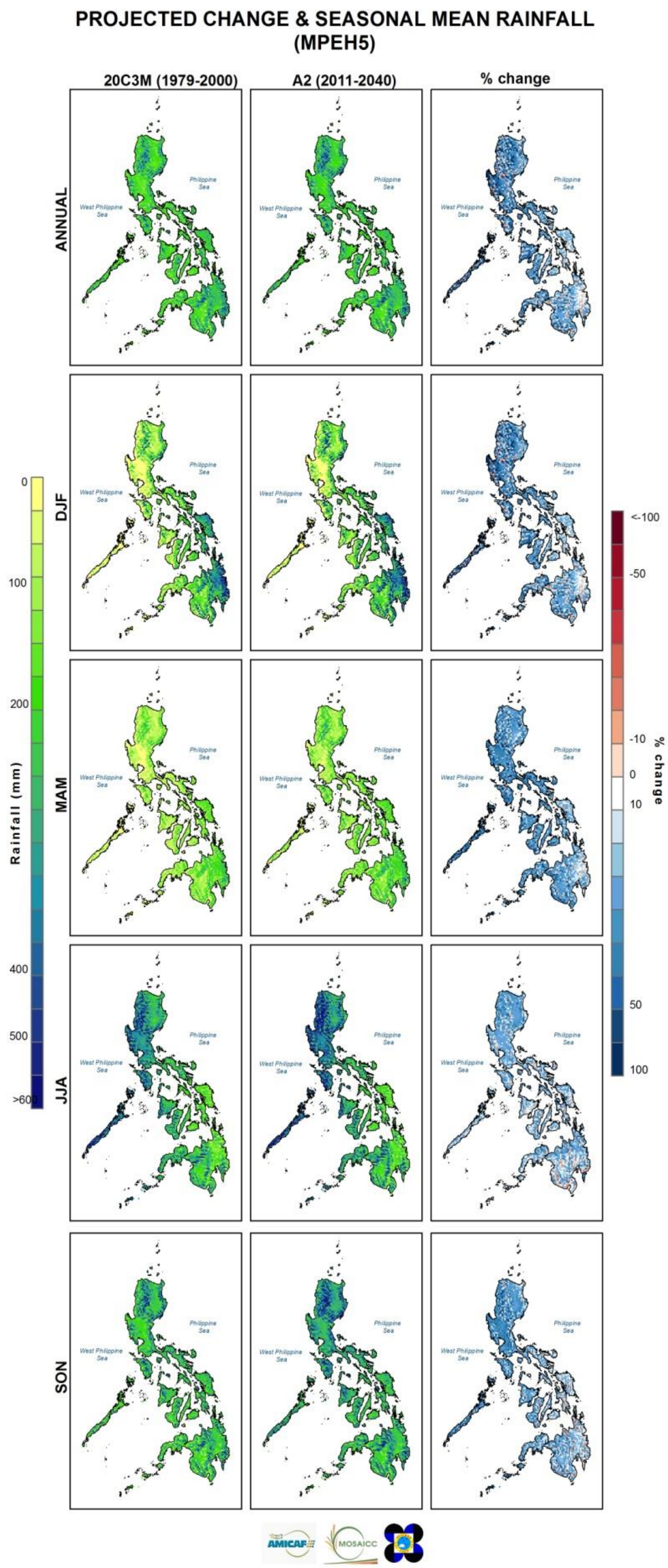


Figure A-15. Projected Seasonal Rainfall & Change under A2 Scenario using MPEH5

ANNEX B

Comparison of Projected Mean Temperature and Changes

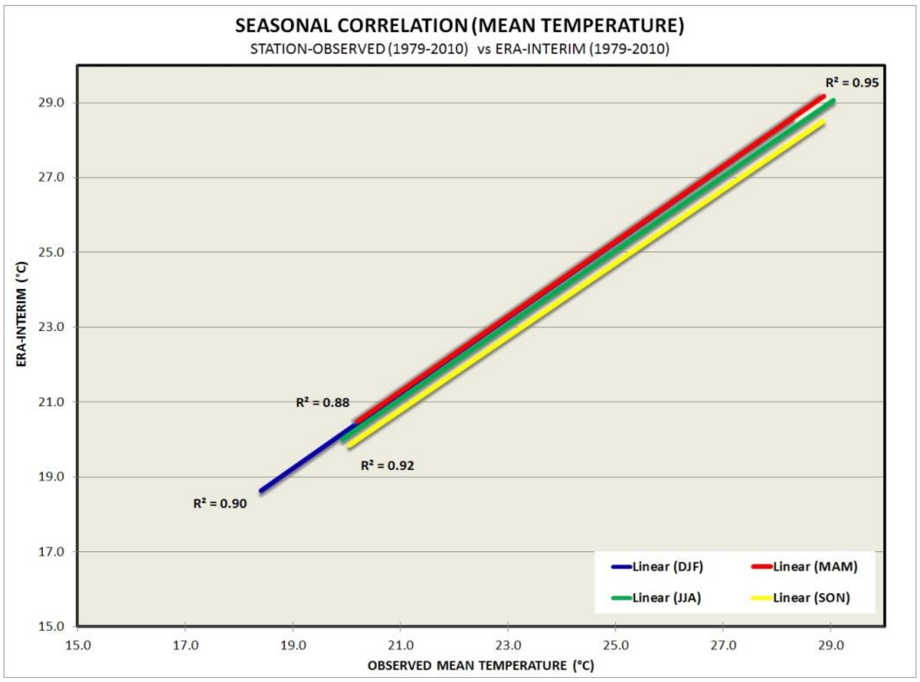


Figure B-1. Comparison of Seasonal Mean Temperature from PAGASA Observations (1979-2010) versus ERA-INTERIM (1979-2010)

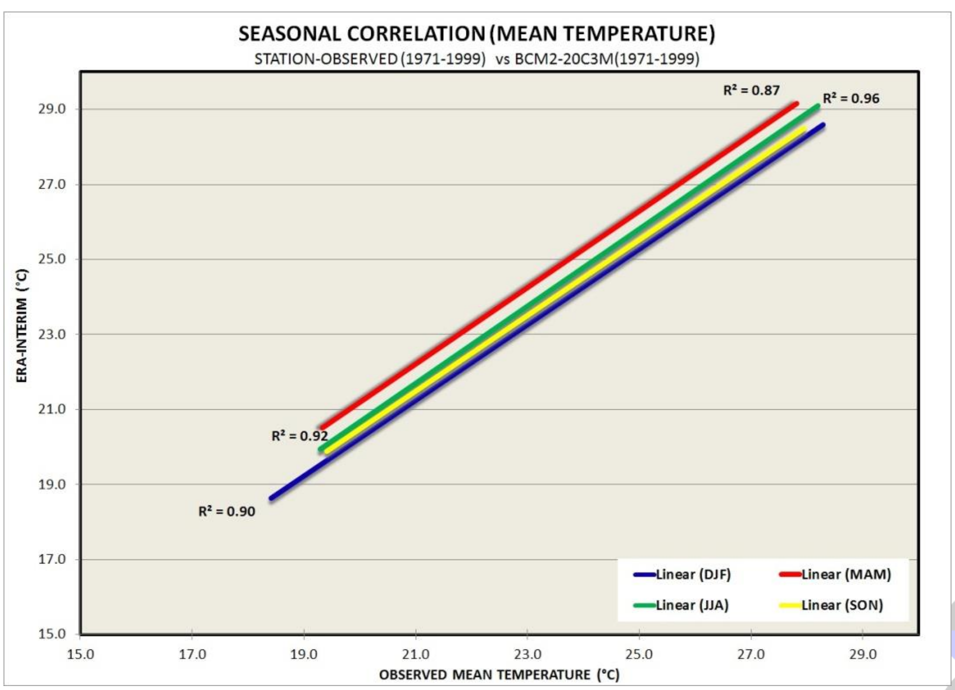


Figure B-2. Comparison of Seasonal Mean Temperature from PAGASA Observations (1979-2010) versus BCM2-20C3M (1979-2010)

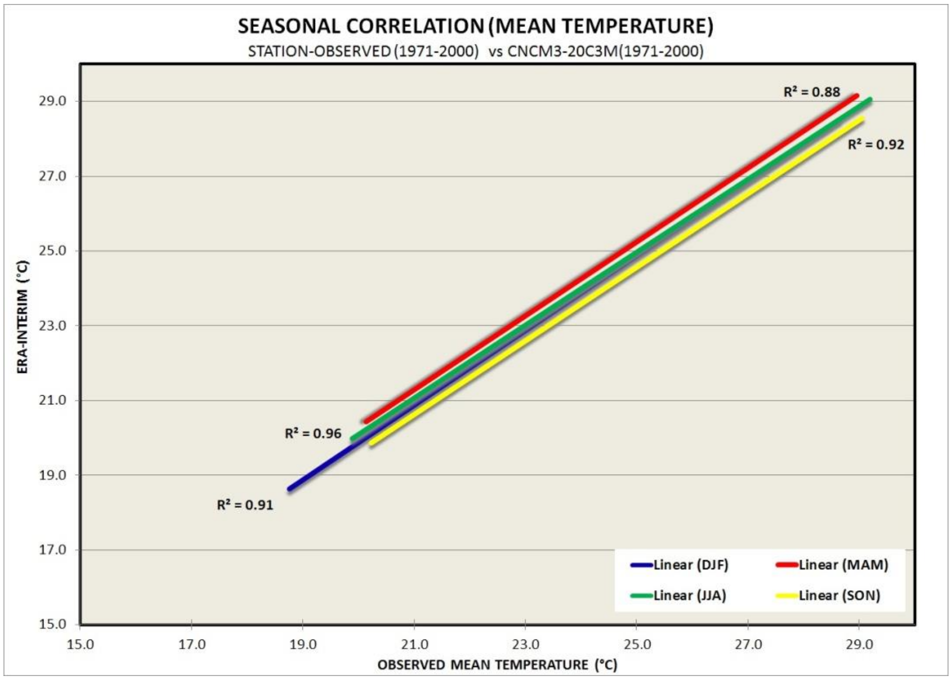


Figure B-3. Comparison of Seasonal Mean Temperature from PAGASA Observations (1979-2010) versus CNCM3-20C3M (1979-2010)

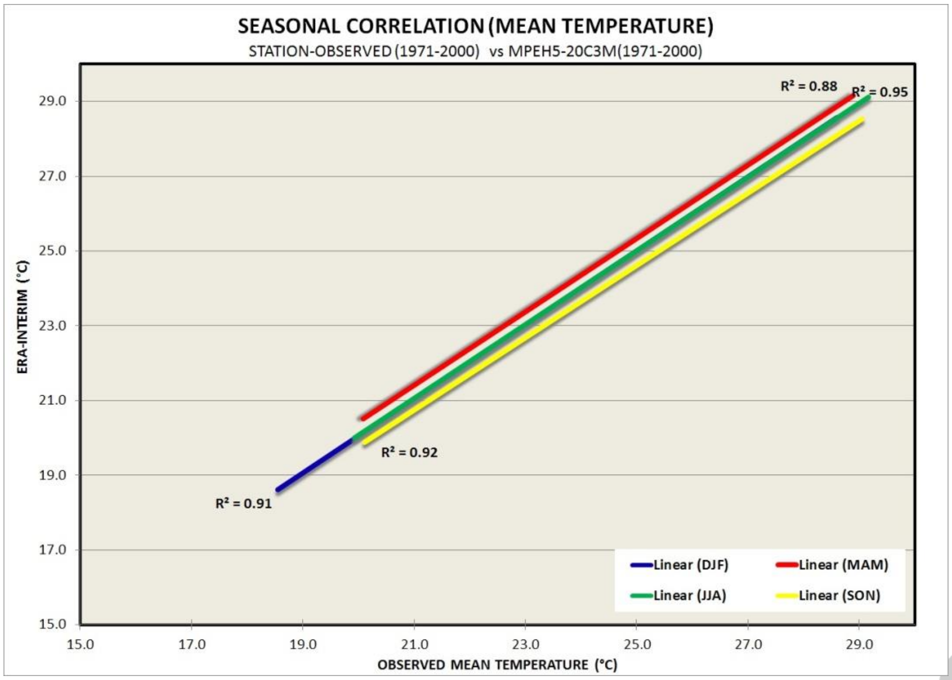


Figure B-4. Comparison of Seasonal Mean Temperature from PAGASA Observations (1979-2010) versus MPEH5-20C3M (1979-2010)

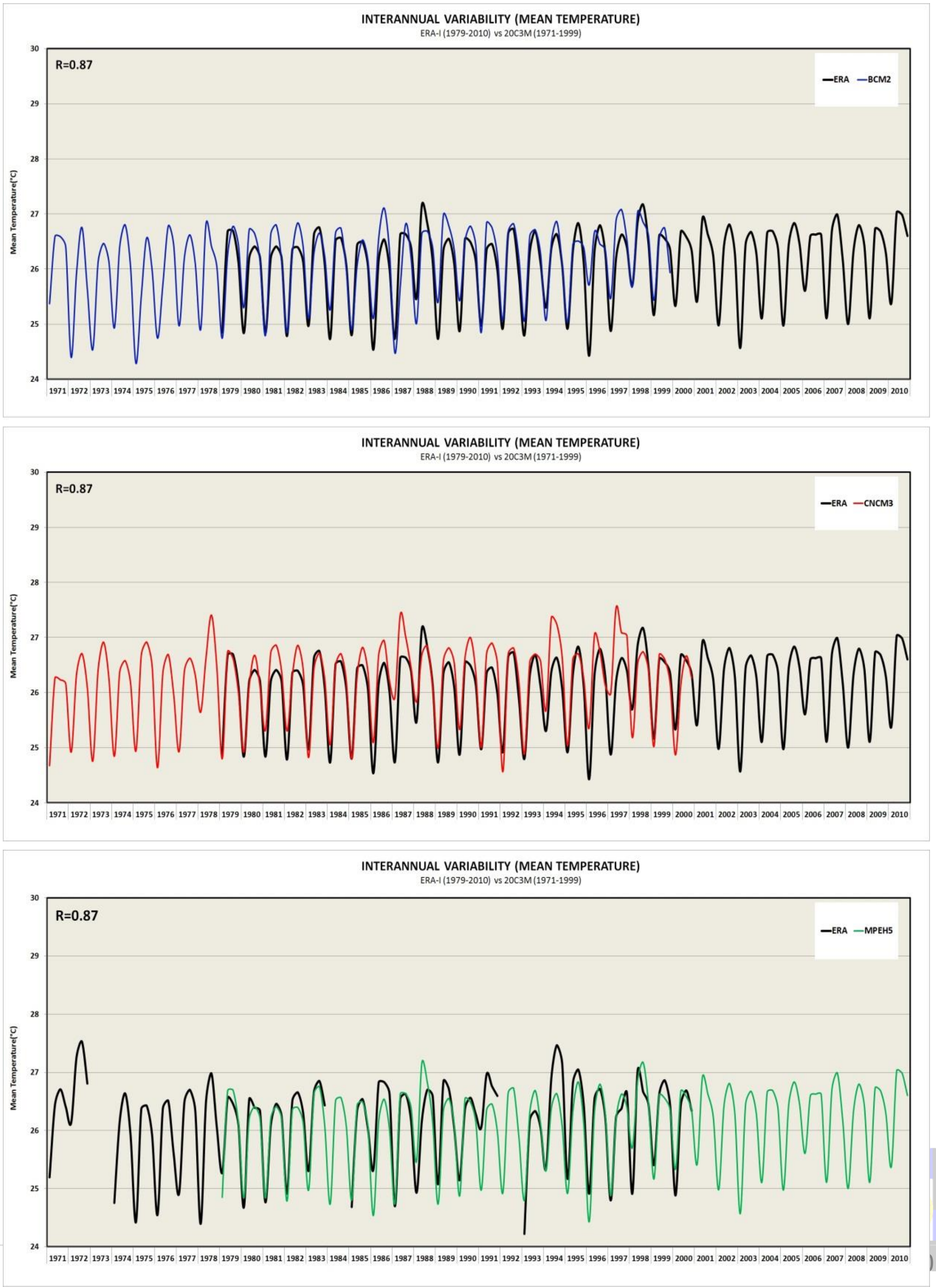


Figure B-5. Interannual Mean Temperature Variability comparing ERA-INTERIM (1979-2010) and BCM2-20C3M (*Figure B-5.a*), CNCM3-20C3M (*Figure B-5.b*), and MPEH5-20C3M (*Figure B-5.c*)

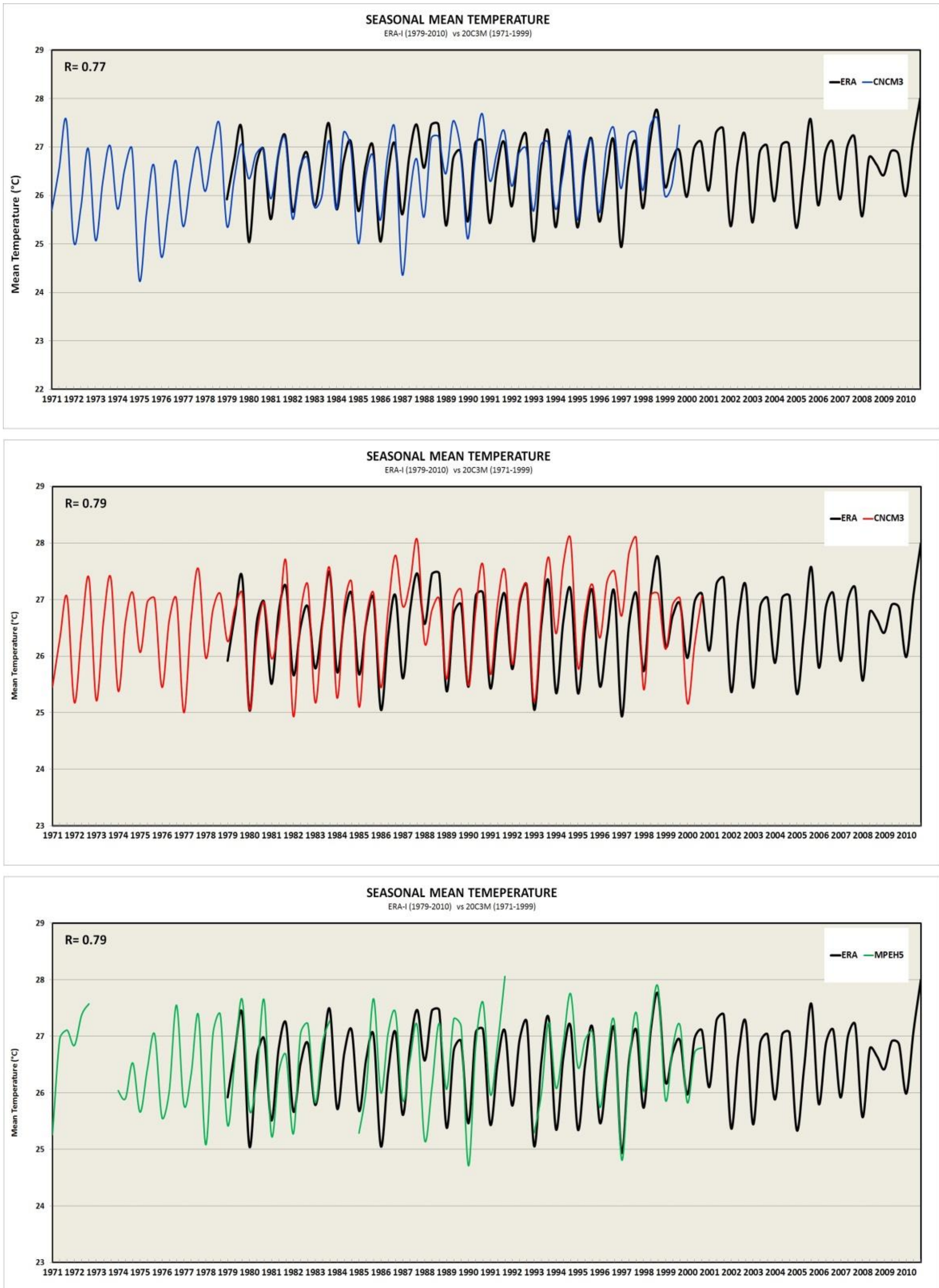
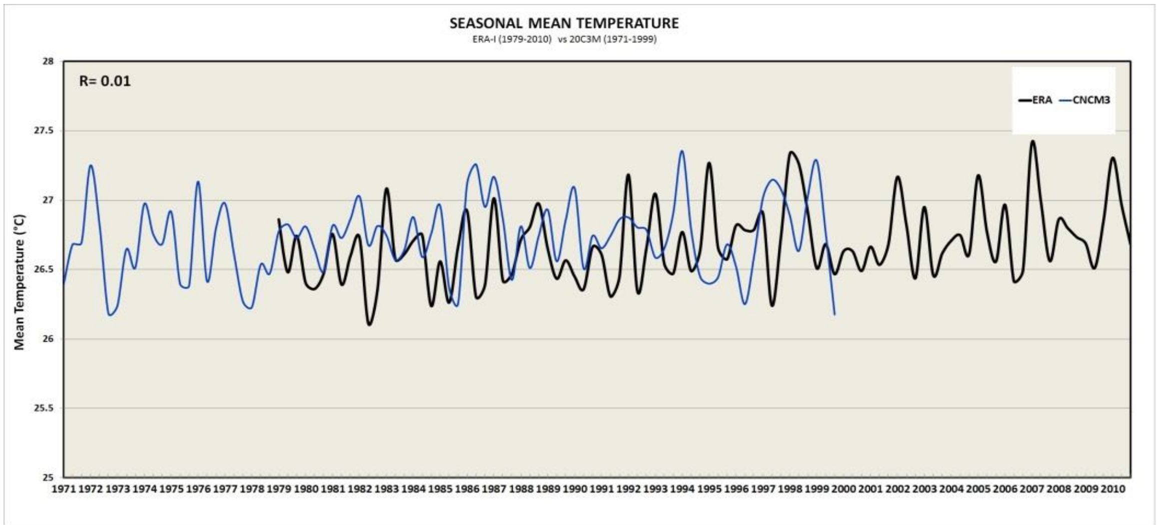
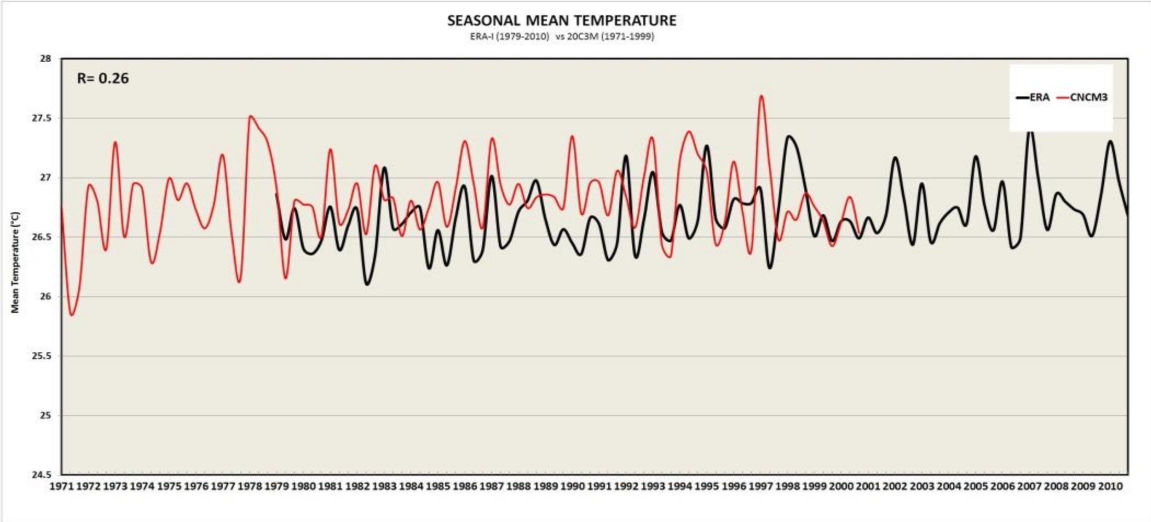


Figure B-6. Seasonal (**March-April-May**) Mean Temperature comparing ERA-INTERIM (1979-2010) and BCM2-20C3M (*Figure B-6.a*), CNCM3-20C3M (*Figure B-6.b*), and MPEH5-20C3M (*Figure B-6.c)*





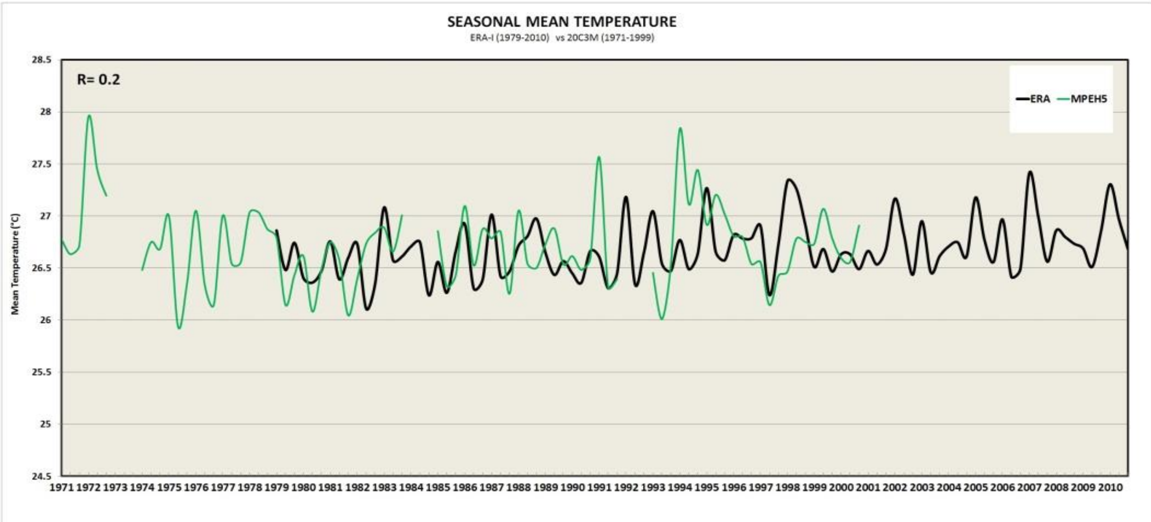
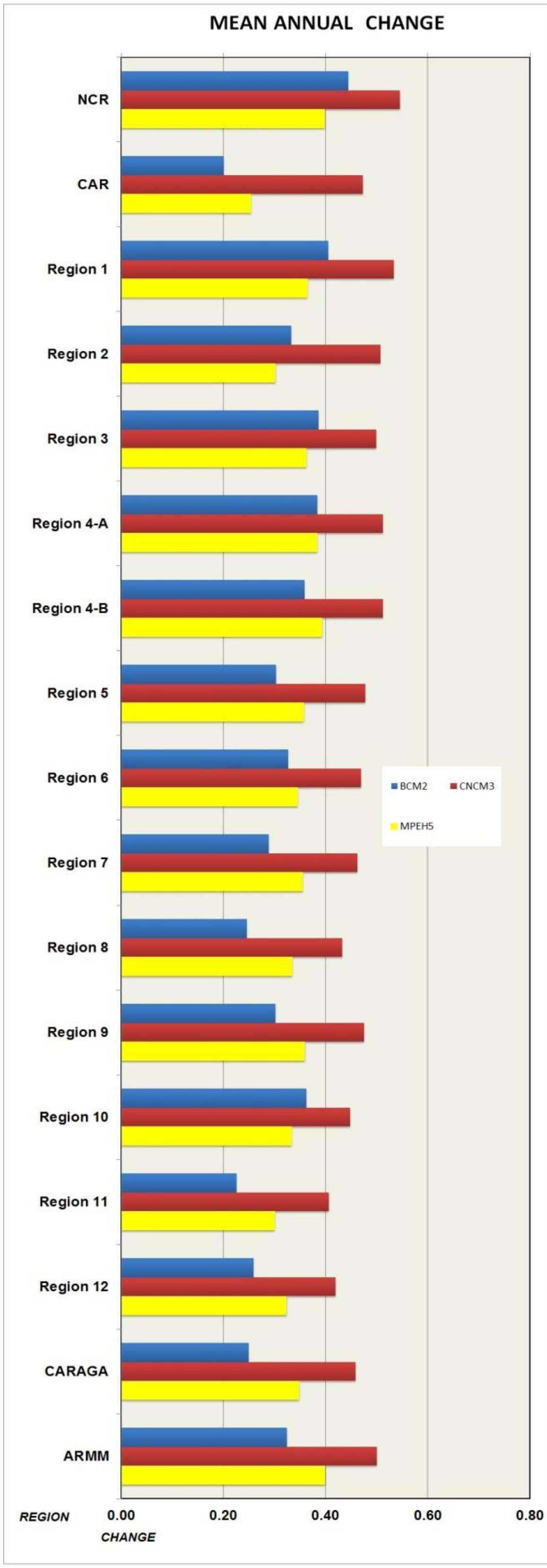


Figure B-7. Seasonal (**June-July-August**) Mean Temperature comparing ERA-INTERIM (1979-2010)

and BCM2-20C3M (*Figure B-7.a*), CNCM3-20C3M (*Figure B-7.b*), and MPEH5-20C3M (*Figure B-7.c)*


MEAN ANNUAL CHANGE
NCR
CAR
Region 1
Region 2
Region 3
Region 4-A
Region 4-B
Region 5
Region 6
Region 7
Region 8
Region 9
Region 10
Region 11
Region 12
CARAGA
ARMM
BCM2
CNCM3
MPEH5
REGION
CHANGE
0.00
0.20
0.40
0.60
0.80

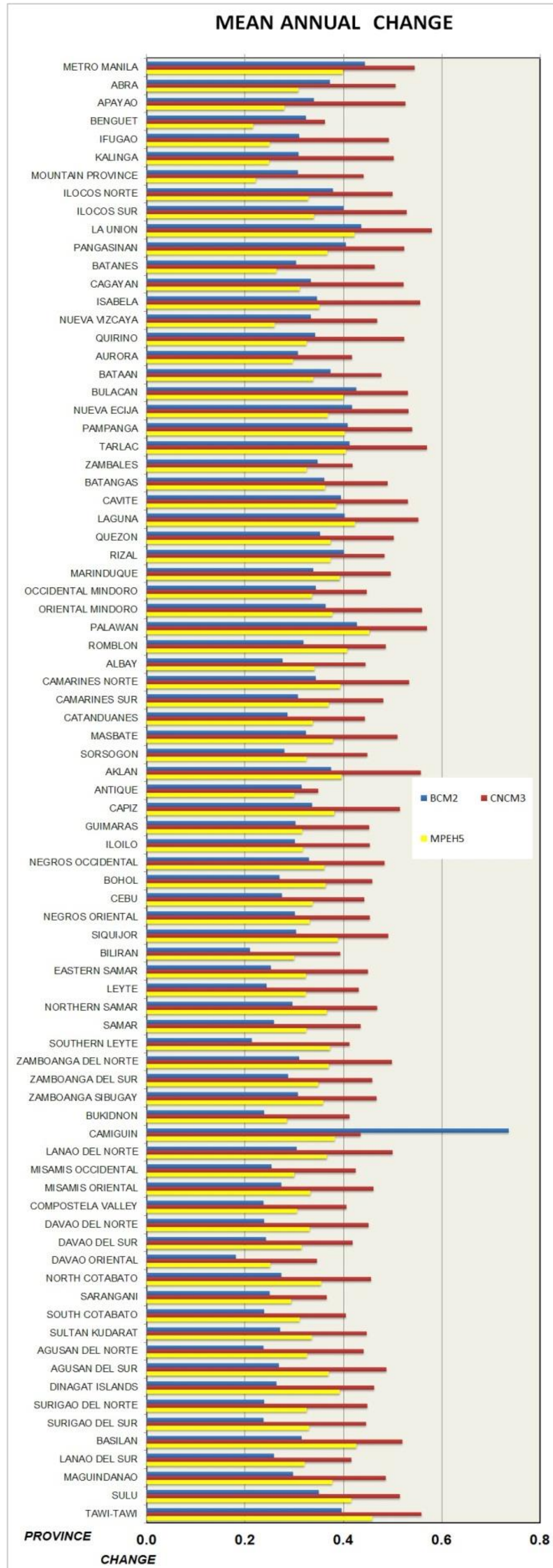
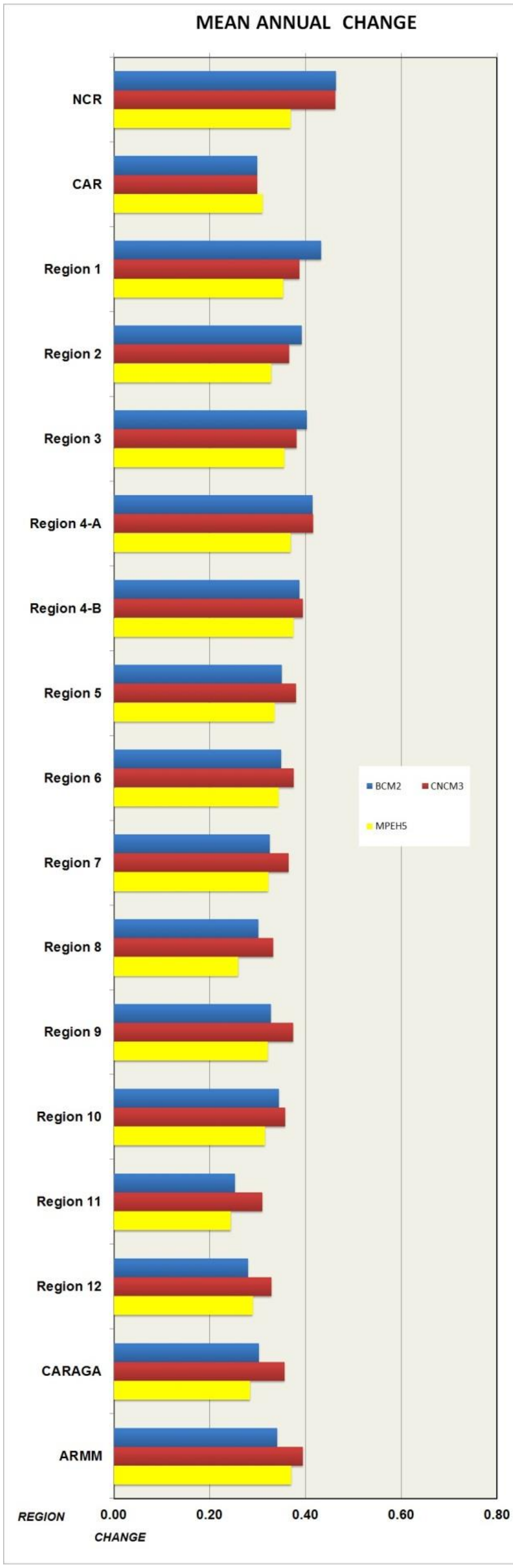

MEAN ANNUAL CHANGE
METRO MANILA
ABRA
APAYAO
BENGUET
IFUGAO
KALINGA
MOUNTAIN PROVINCE
ILOCOS NORTE
ILOCOS SUR
LA UNION
PANGASINAN
BATANES
CAGAYAN
ISABELA
NUEVA VIZCAYA
QUIRINO
AURORA
BATAAN
BULACAN
NUEVA ECIJA
PAMPANGA
TARLAC
ZAMBALES
BATANGAS
CAVITE
LAGUNA
QUEZON
RIZAL
MARINDUQUE
OCCIDENTAL MINDORO
ORIENTAL MINDORO
PALAWAN
ROMBLON
ALBAY
CAMARINES NORTE
CAMARINES SUR
CATANDUANES
MASBATE
SORSOGON
AKLAN
ANTIQUE
CAPIZ
GUIMARAS
ILOILO
NEGROS OCCIDENTAL
BOHOL
CEBU
NEGROS ORIENTAL
SIQUIJOR
BILIRAN
EASTERN SAMAR
LEYTE
NORTHERN SAMAR
SAMAR
SOUTHERN LEYTE
ZAMBOANGA DEL NORTE
ZAMBOANGA DEL SUR
ZAMBOANGA SIBUGAY
BUKIDNON
CAMIGUIN
LANAO DEL NORTE
MISAMIS OCCIDENTAL
MISAMIS ORIENTAL
COMPOSTELA VALLEY
DAVAO DEL NORTE
DAVAO DEL SUR
DAVAO ORIENTAL
NORTH COTABATO
SARANGANI
SOUTH COTABATO
SULTAN KUDARAT
AGUSAN DEL NORTE
AGUSAN DEL SUR
DINAGAT ISLANDS
SURIGAO DEL NORTE
SURIGAO DEL SUR
BASILAN
LANAO DEL SUR
MAGUINDANAO
SULU
TAWI-TAWI
BCM2
CNCM3
MPEH5
PROVINCE
CHANGE
0.0
0.2
0.4
0.6
0.8

Figure B-8. Mean Annual Temperature Change under A1B Scenario using the average of three GCMs



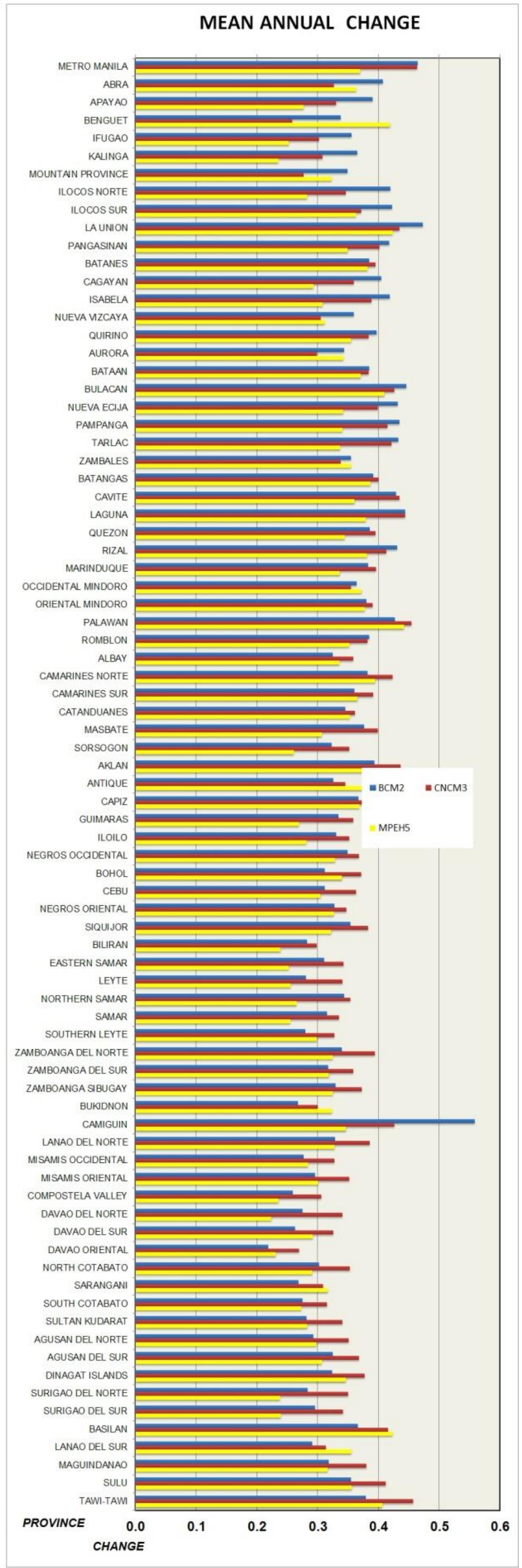
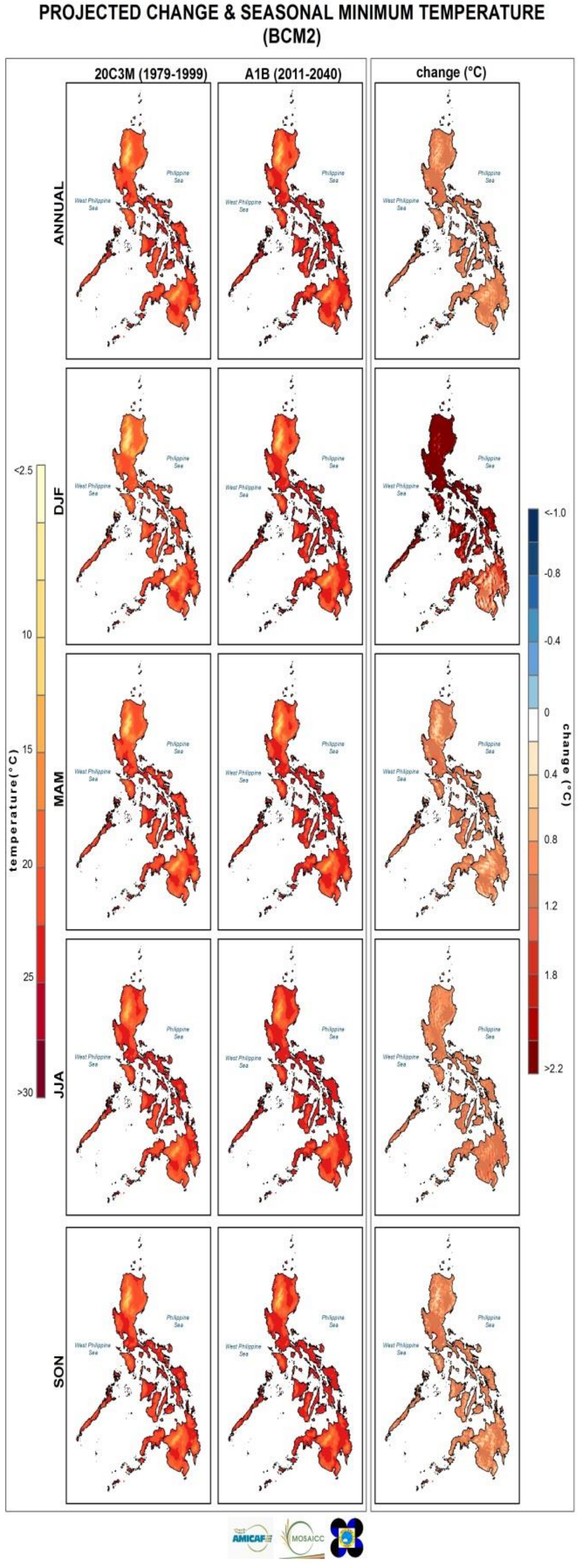


Figure B-9. Mean Annual Temperature Change under A2 Scenario using the average of three GCMs



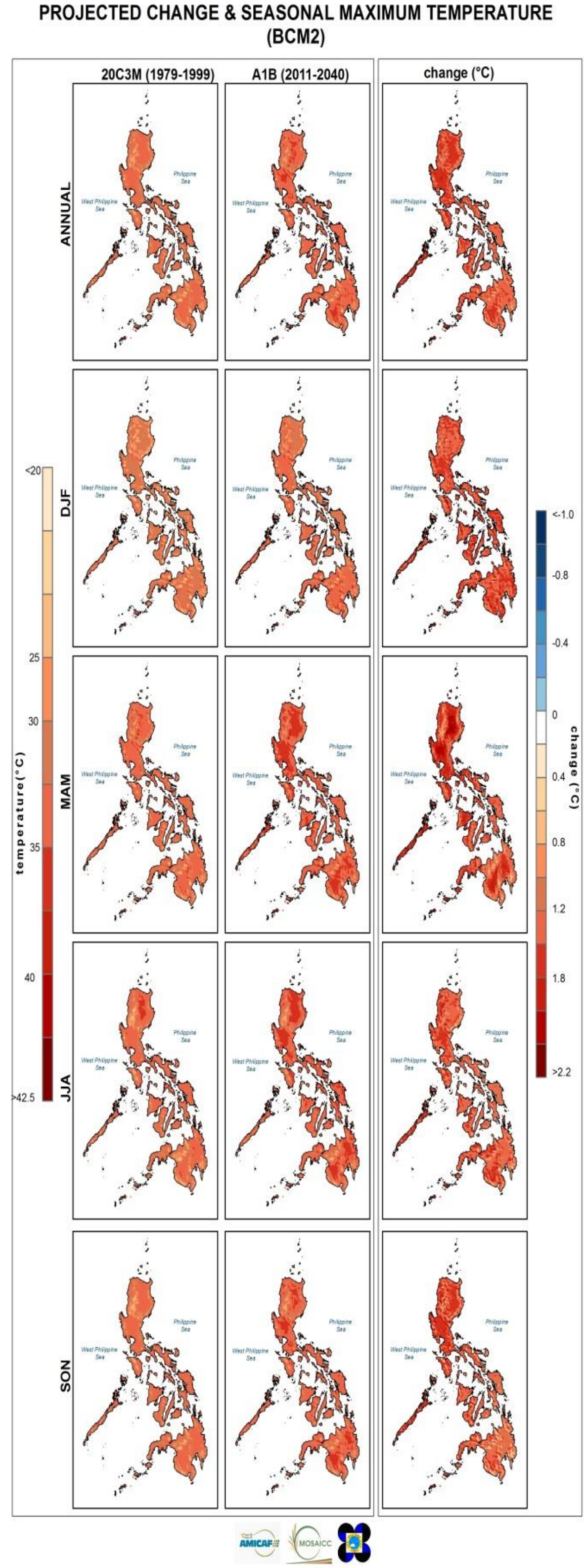


Figure B-10. Projected Change & Seasonal Temperature (Maximum and Minimum) under A1B Scenario using BCM2

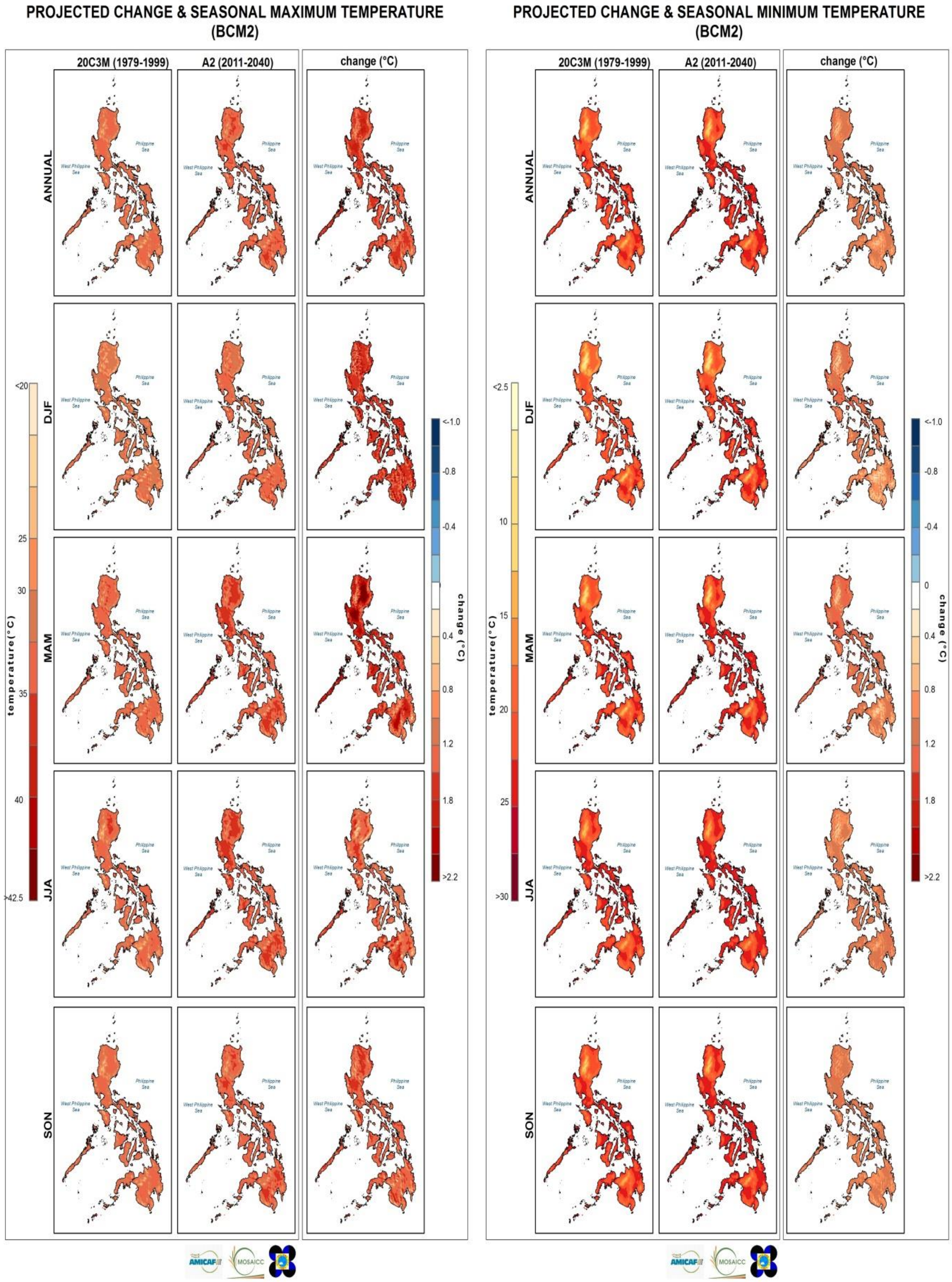
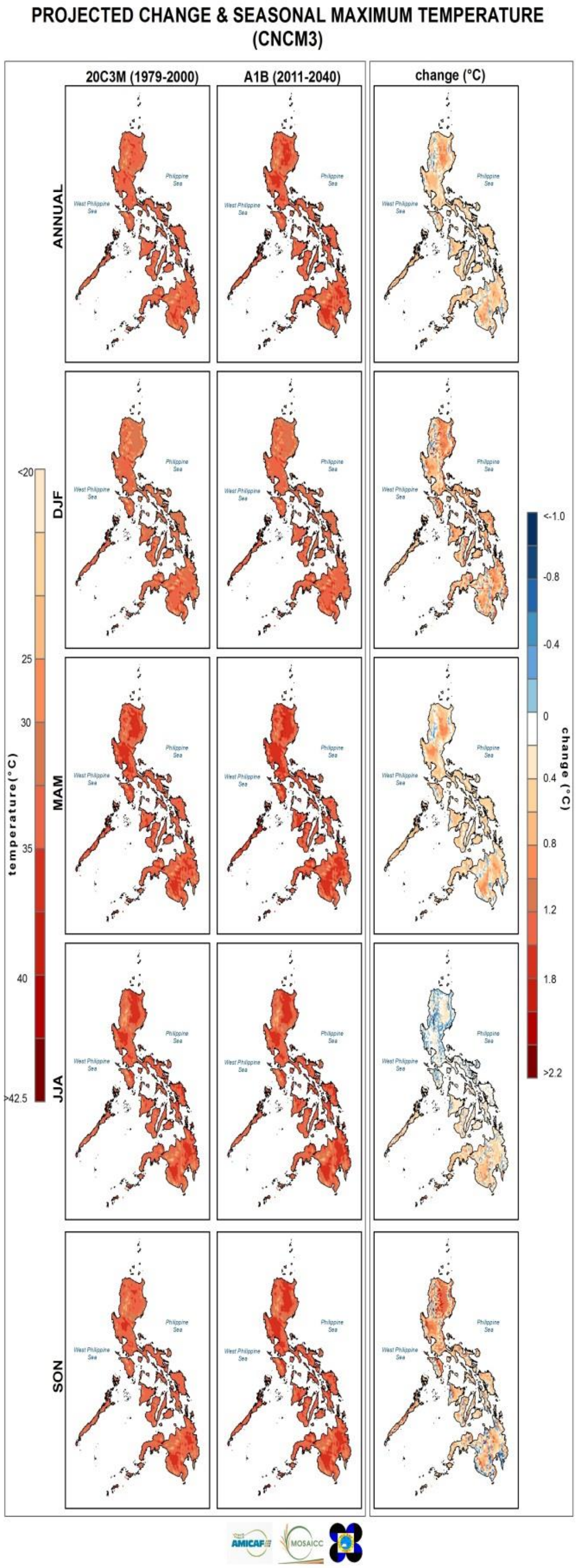


Figure B-11. Projected Change & Seasonal Temperature (Maximum and Minimum) under A2 Scenario

using BCM2


PROJECTED CHANGE & SEASONAL MAXIMUM TEMPERATURE
(CNCM3)
20C3M (1979-2000)
A1B (2011-2040)
change (°C)
ANNUAL
DJF
MAM
JJA
SON
temperature(°C)
<20
25
30
35
40
>42.5
change (°C)
<-1.0
-0.8
-0.4
0
0.4
0.8
1.2
1.8
>2.2
Philippine Sea
West Philippine Sea

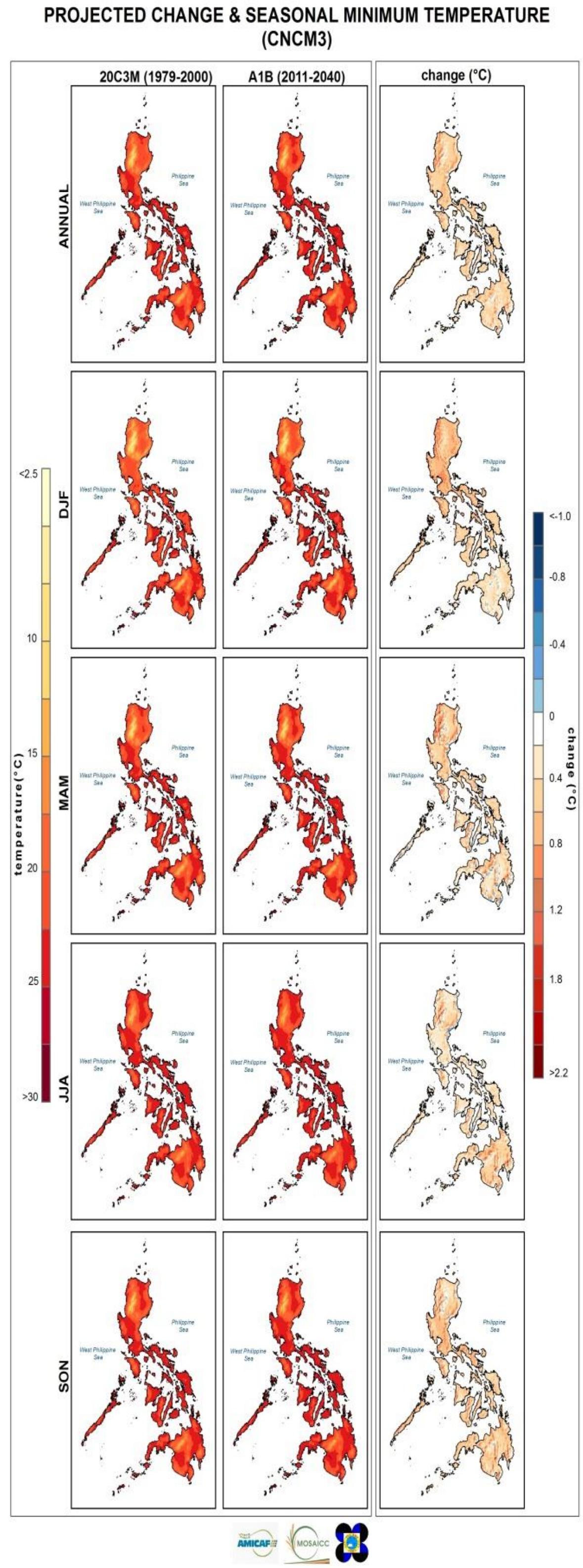
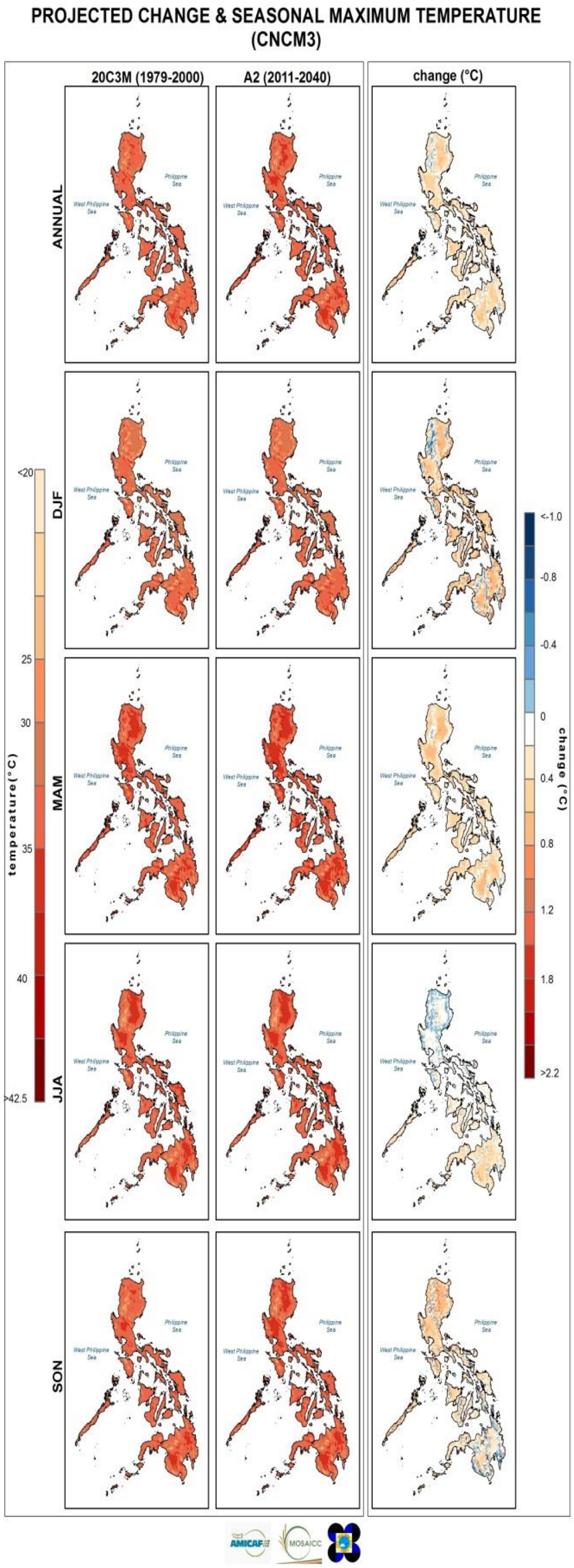

PROJECTED CHANGE & SEASONAL MINIMUM TEMPERATURE
(CNCM3)
20C3M (1979-2000)
A1B (2011-2040)
change (°C)
ANNUAL
DJF
MAM
JJA
SON
temperature(°C)
<2.5
10
15
20
25
>30
change (°C)
<-1.0
-0.8
-0.4
0
0.4
0.8
1.2
1.8
>2.2
Philippine Sea
West Philippine Sea

Figure B-12. Projected Change & Seasonal Temperature (Maximum and Minimum) under A1B Scenario using CNCM3



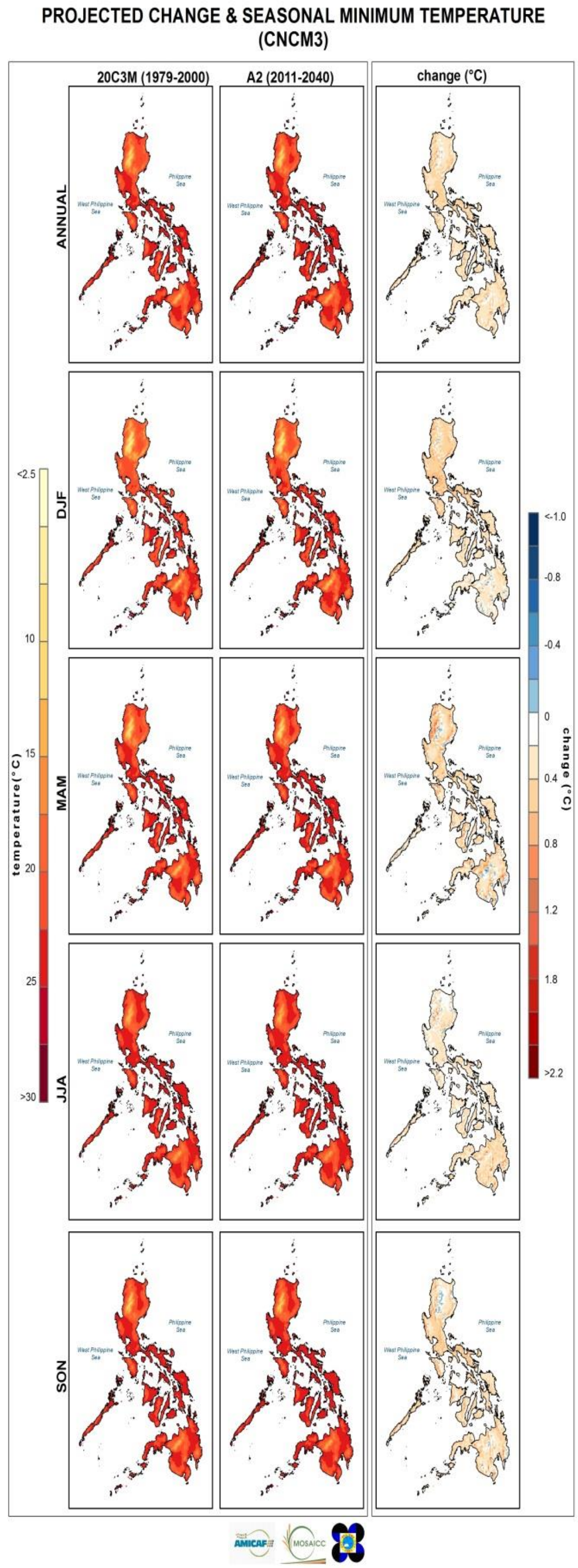


Figure B-13. Projected Change & Seasonal Temperature (Maximum and Minimum) under A2 Scenario using CNCM

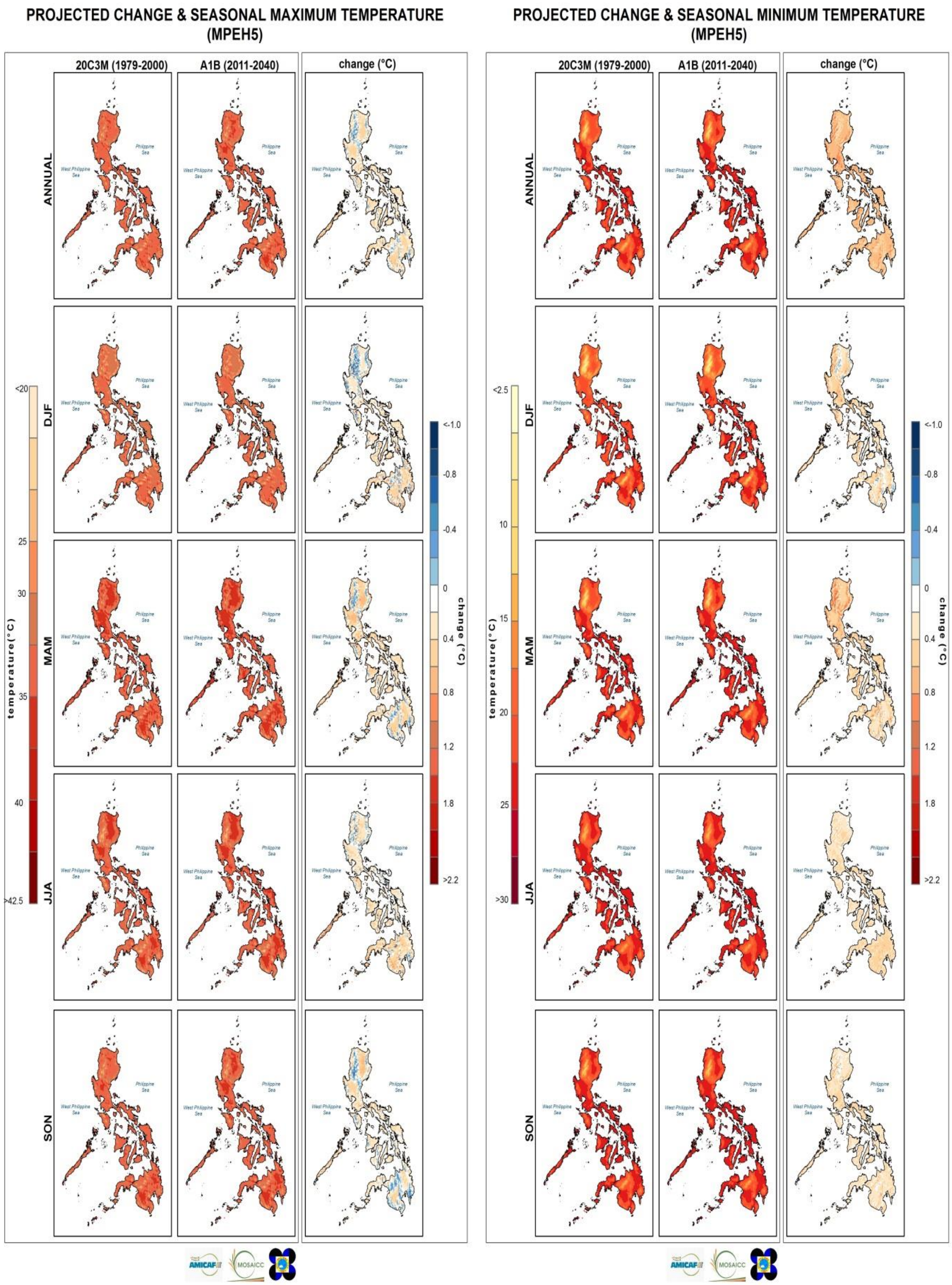


Figure B-14. Projected Change & Seasonal Temperature (Maximum and Minimum) under A1B Scenario using MPEH5

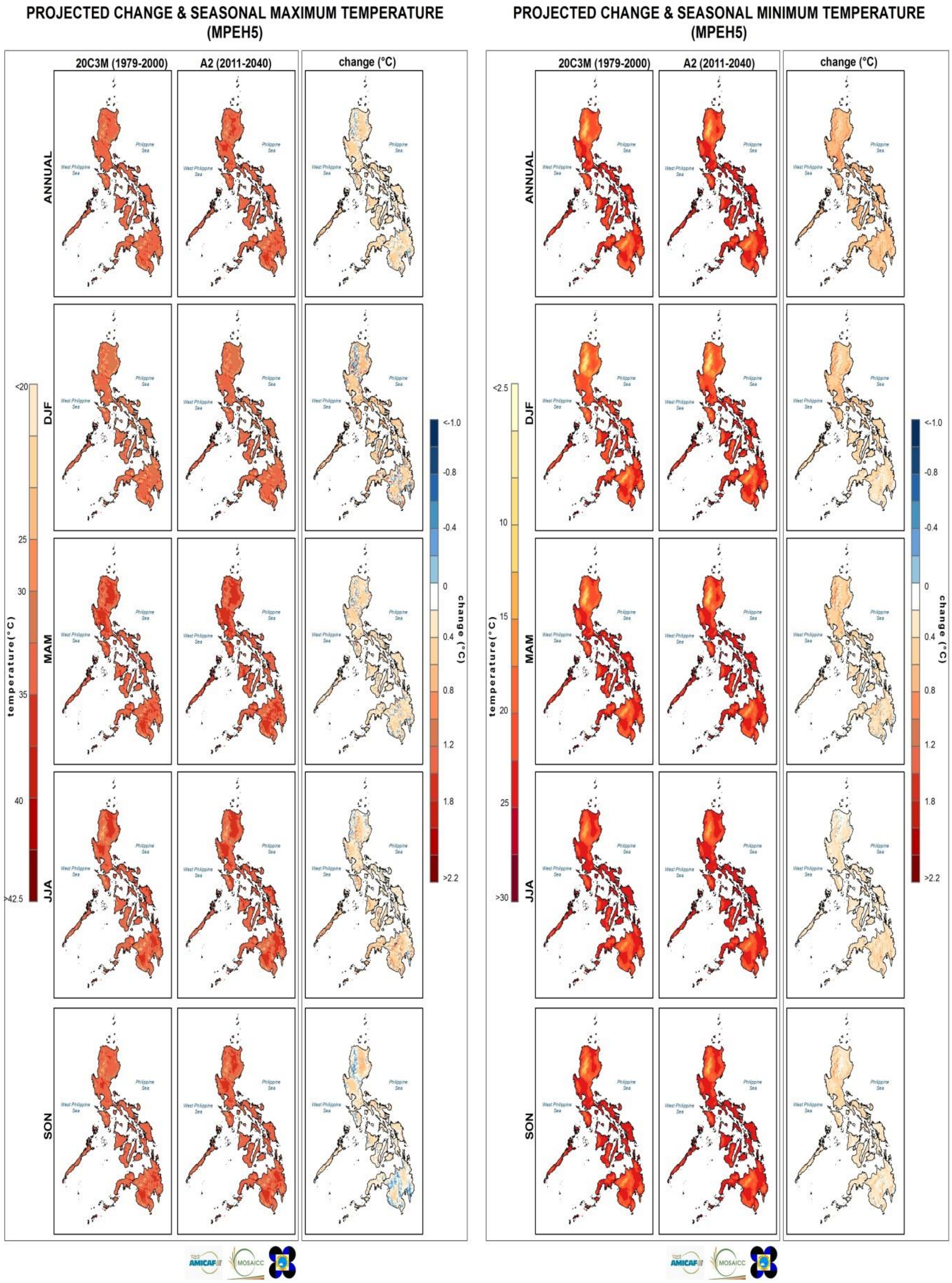


Figure B-15. Projected Change & Seasonal Temperature (Maximum and Minimum) under A2 Scenario using MPEH5

ANNEX C

Frequency of Extreme Events

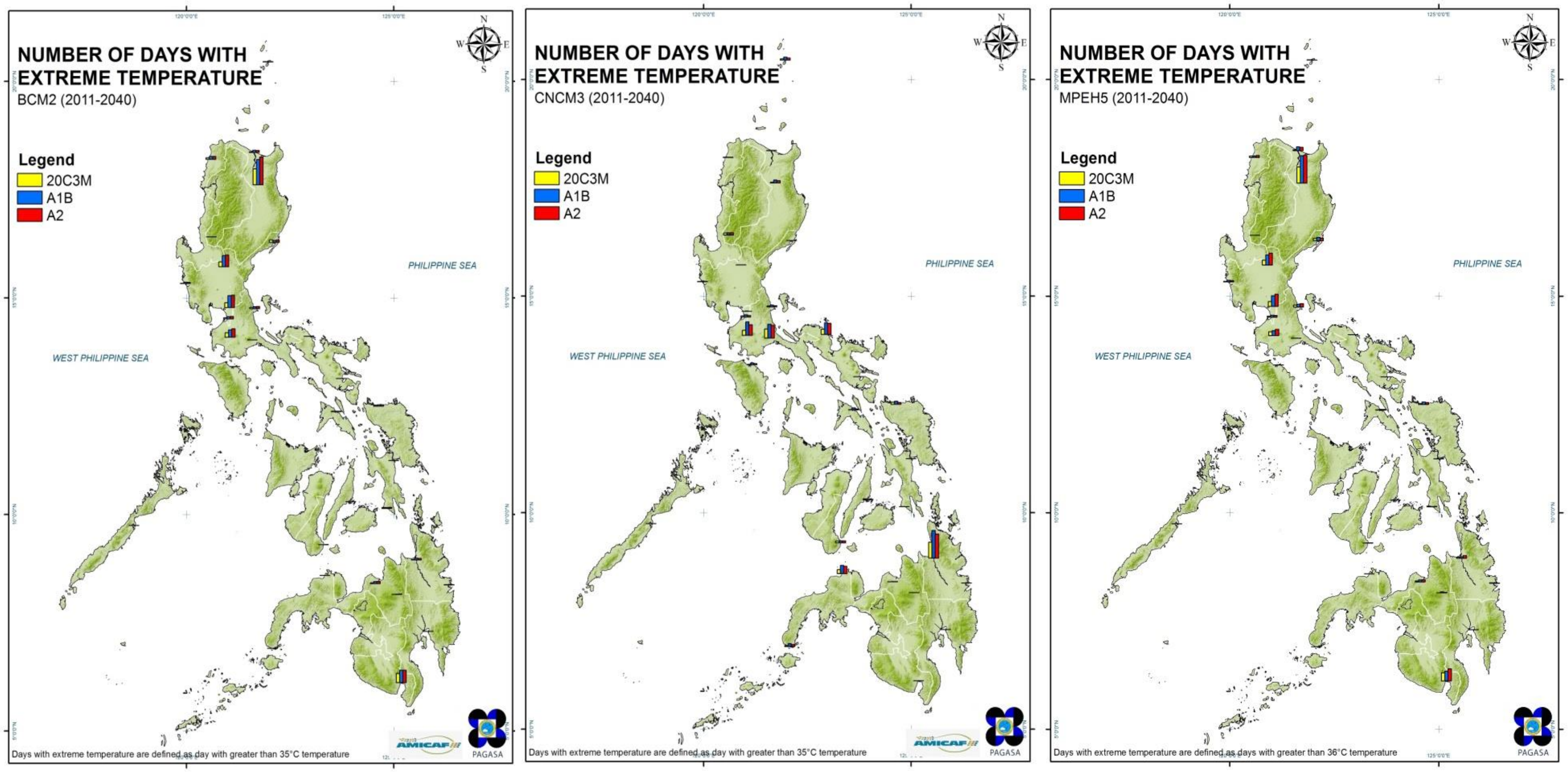


Figure C-1. **Number of Days with Maximum Temperature Exceeding 35°C: BCM2 (*Figure C-1.a*), CNCM3 (*Figure C-1.b*), and MPEH5 (*Figure C-1.c*)**

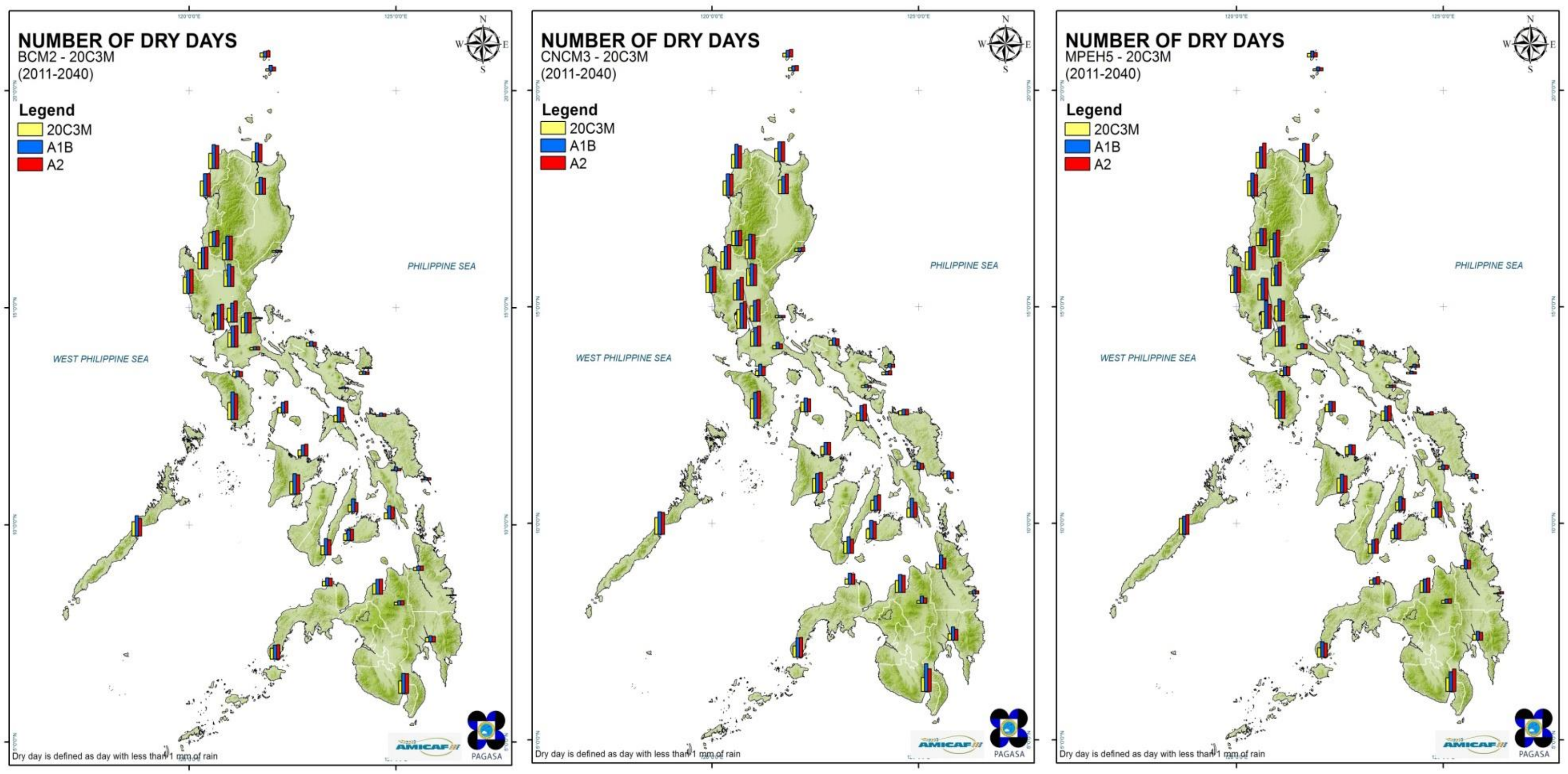


Figure C-2. Number of Dry Days (5 consecutive days with <1 mm of daily rainfall): BCM2 (*Figure C-2.a*), CNCM3 (*Figure C-2.b),* and MPEH5 (*Figure C-2.c*)

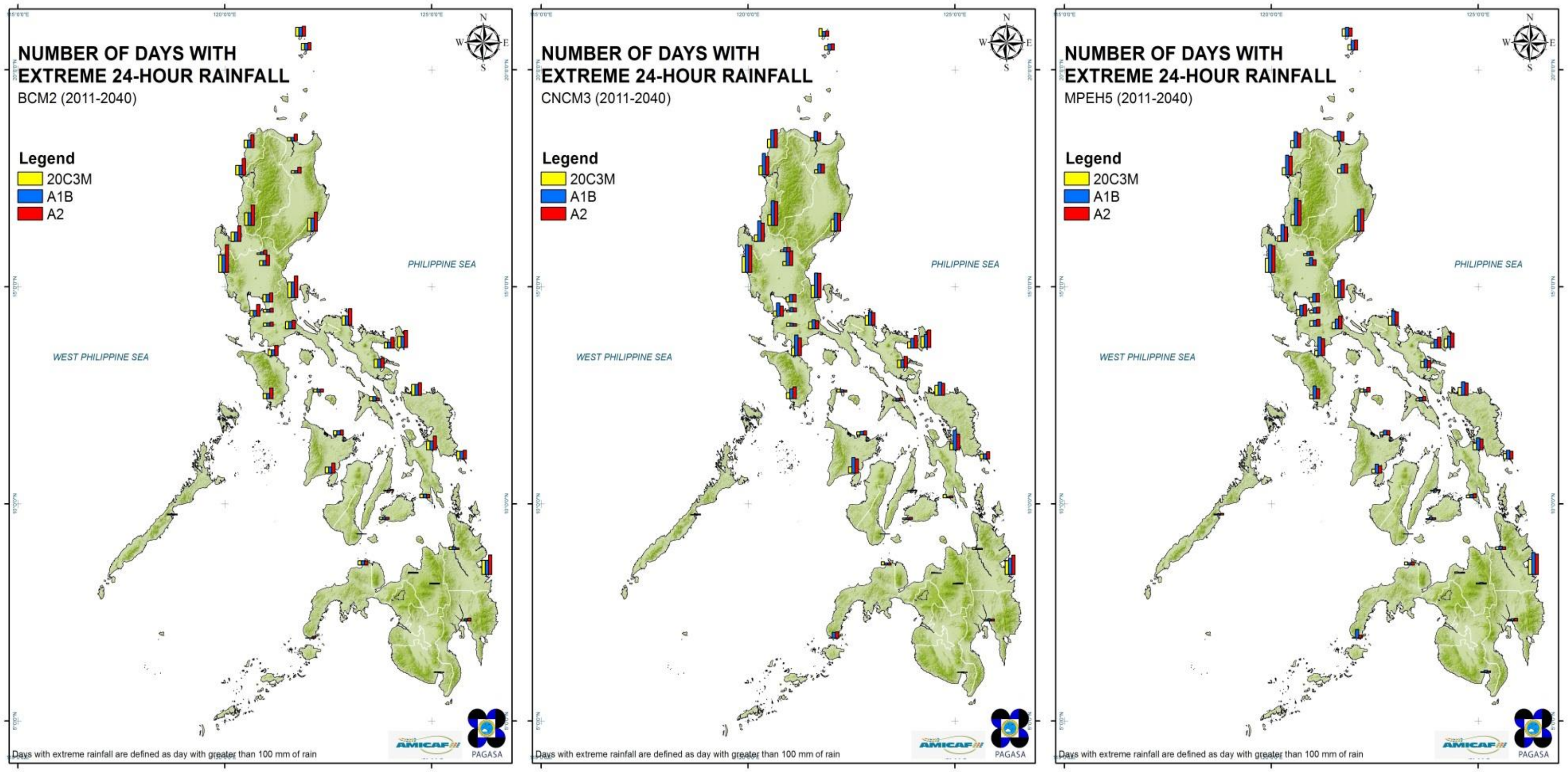


Figure C-3. Number of Days with Extreme Daily Rainfall exceeding >= 100 mm of daily rainfall: BCM2 (*Figure C-3.a*), CNCM3 (*Figure C-3.b*), and MPEH5 (*Figure C-3.c)*