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

Generation of Coupled Model Intercomparison Project Phase 5 Earth System Model Climate Projections

Program: FAO-AMICAF Philippines

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Table of Contents

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 Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) and the Food and Agriculture Organization of the United Nations (FAO) 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) 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 stands 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. The first of which is the statistical downscaling of Earth System Models (ESMs) to PAGASA station level. Analyse Utilisant le RElief pour l'Hydrométéorologie (AURELHY) technique is employed to interpolate projected values to 10 km horizontal resolution.

In 2011, PAGASA completed the first phase of AMICAF-Step1 which is the climate scenario downscaling. Results obtained from the computer runs were compiled, processed, and provided to next participating institutions for further studies. These institutions include 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). 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 the AMICAF Step 1 Phase 1 (hereinafter referred to as Step 1-P2) can be downloaded via http://www.pagasa.dost.gov.ph/index.php/climate/climate-projection where a technical note can also be retrieved by end-users via

https://pubfiles.pagasa.dost.gov.ph/climps/climateprojection/Users_Guide_to_AMICAF.pdf.

There are two publications produced under AMICAF-Step 1 Phase. The first publication was undertaken by Manzanas et al (2015) on the sensitivity of global climate models to actual climate data. Basconcillo et al. (2015) provided a detailed discussion on statistical downscaling employed to generate climate projections and its implication to an agricultural area like Cagayan Valley.

In 2014, the second phase of AMICAF Step 1 (hereinafter referred to as Step 1-P2) commenced with the introduction of Coupled Model Intercomparison Project Phase 5 Representative Concentration Pathways (RCPs). PAGASA, through MOSAICC, downscaled 6 ESMs and 2 RCPs under the two time period: 2020-2049 and 2050 - 2079.

The project concluded in December 2015. A paper describing the methodology of Step1-P2 is currently being written by the project team.

INTRODUCTION TO COUPLED MODEL INTERCOMPARISON PROJECT PHASE 5

Previous climate change projection based on IPCC Fourth Assessment Report (AR4), Special Report on Emissions Scenarios (SRES) or storylines were used to describe a future world based on projected future greenhouse gas (GHG) emissions since 20th century. But with the growing availability of data on changing climate patterns, advances in computing and atmospheric sciences, and availability of observed GHGs, the IPCC released in 2013 its Fifth Assessment Report (AR5) shifting from previous SRES to Representative Concentration Pathways (RCPs). The primary difference of the two climate change scenarios is attributed to the integration of observed GHG concentrations in climate projection in the latter proved to be lacking in previous version of climate models.

While CMIP5 addresses some issues related to the performance of AR4 models, there are still uncertainties on its application for statistical downscaling especially in the Philippines where topography and geography play large roles in defining its climate. To overcome such issues this project used and analyze the application of CMIP5 Earth System Models (ESMs) to local climatology particular to climate projections.

This project is expected to provide better climate projections and RCP scenarios necessary for national government agencies (NGAs), non-government organizations (NGOs), and local government units (LGUs) to deliver preventive measures, and prepare for a range of adaptation strategies.

Overview of Philippine Climate

The climate of the Philippines is predominantly influenced by its geographical location and topographic features with several islands, mountain ranges, coastal plains, and wind systems as a result of the seasonal differential heating of neighboring continents and oceans. Figures 1a and 1b show 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.

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).

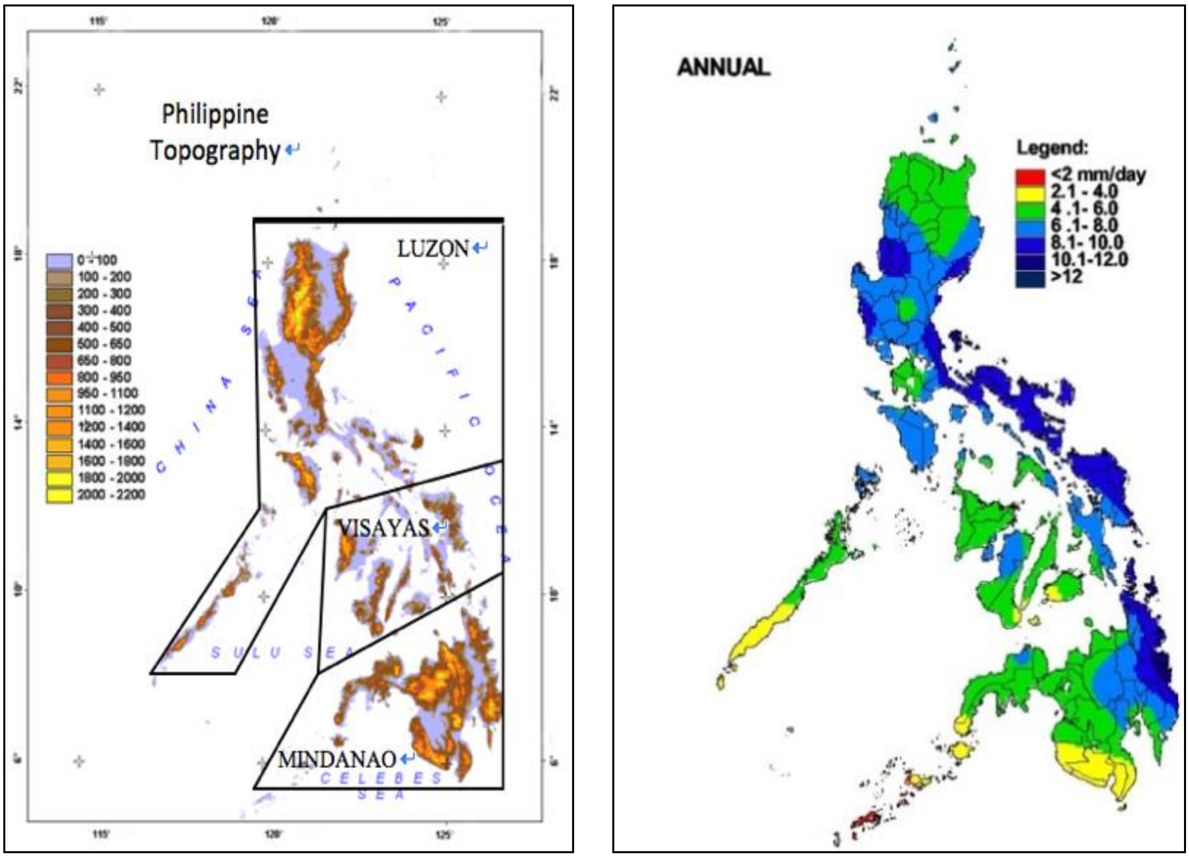


Fig 1. (*a*) Topographic map of the Philippines with delineation of main islands of Luzon, Visayas and Mindanao; (*b*) station-scale interpolated mean annual rainfall distribution (1979-2010) in mm/day.

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 (Tmax/Tmin) do not vary much; and tropical maritime, with uneven rainfall distribution throughout the year and marked high annual rainfall values. Figure 2 shows the semestral rainfall distribution during the two distinct monsoon systems: Northeast Monsoon and Southwest Monsoon.

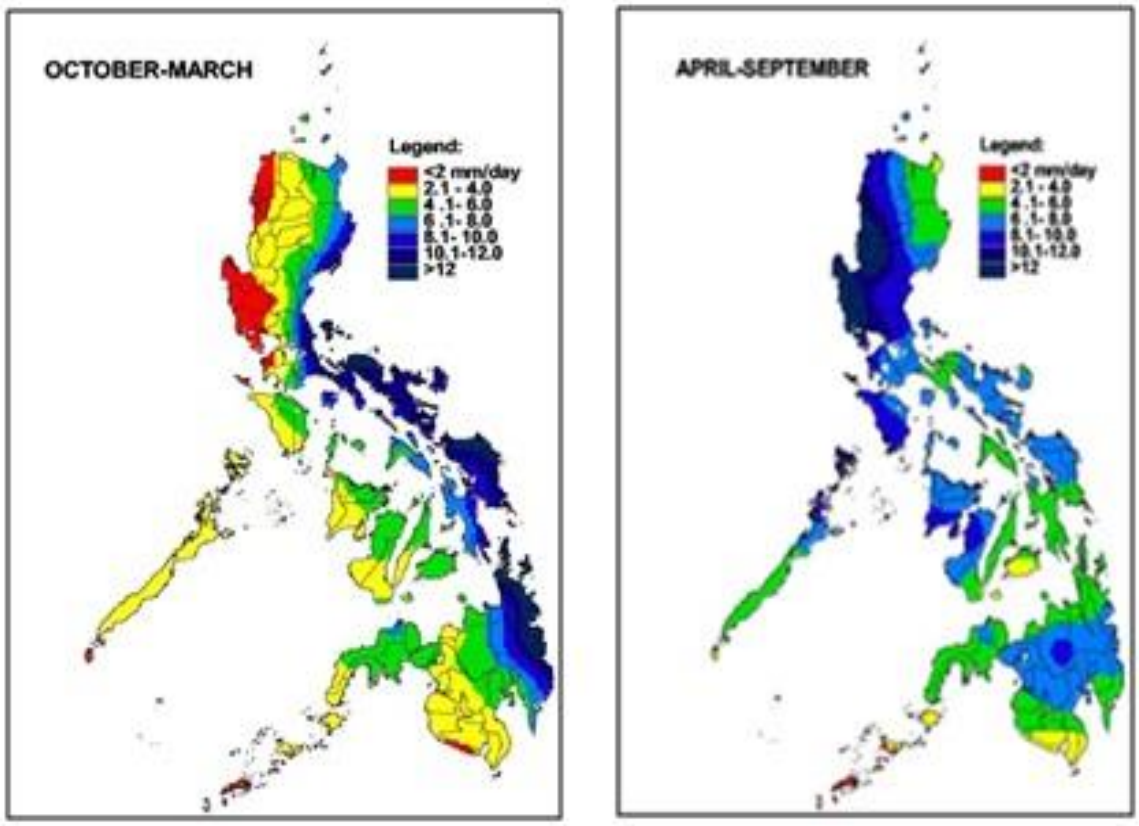
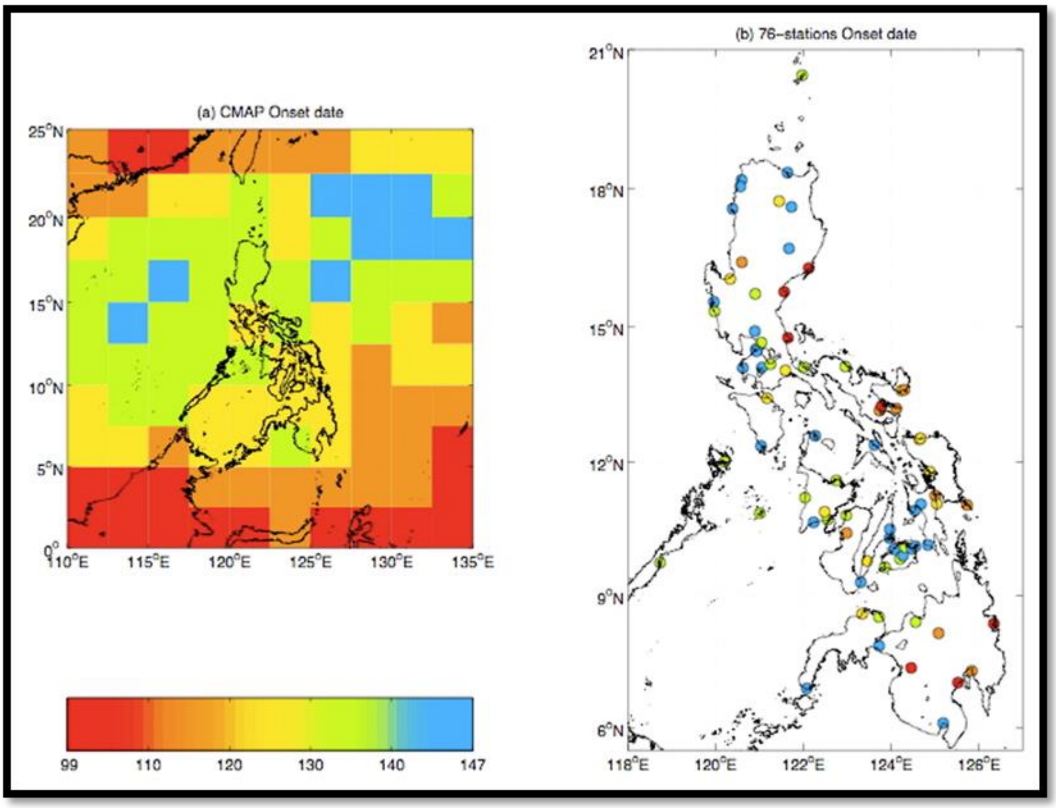


Fig 2. Seasonal rainfall distribution during (*a*) *NE* monsoon and (*b*) SW monsoon. Note that Plots were made out of APHRODITE (Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation of Water Resources) gridded station dataset (Yatagai et.al, 2012)

The onset of rainy season occurs 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 3 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 (Fig. 4). 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).



http://iri.columbia.edu/~awr/TP/Test.jpg

Figure 3. 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.

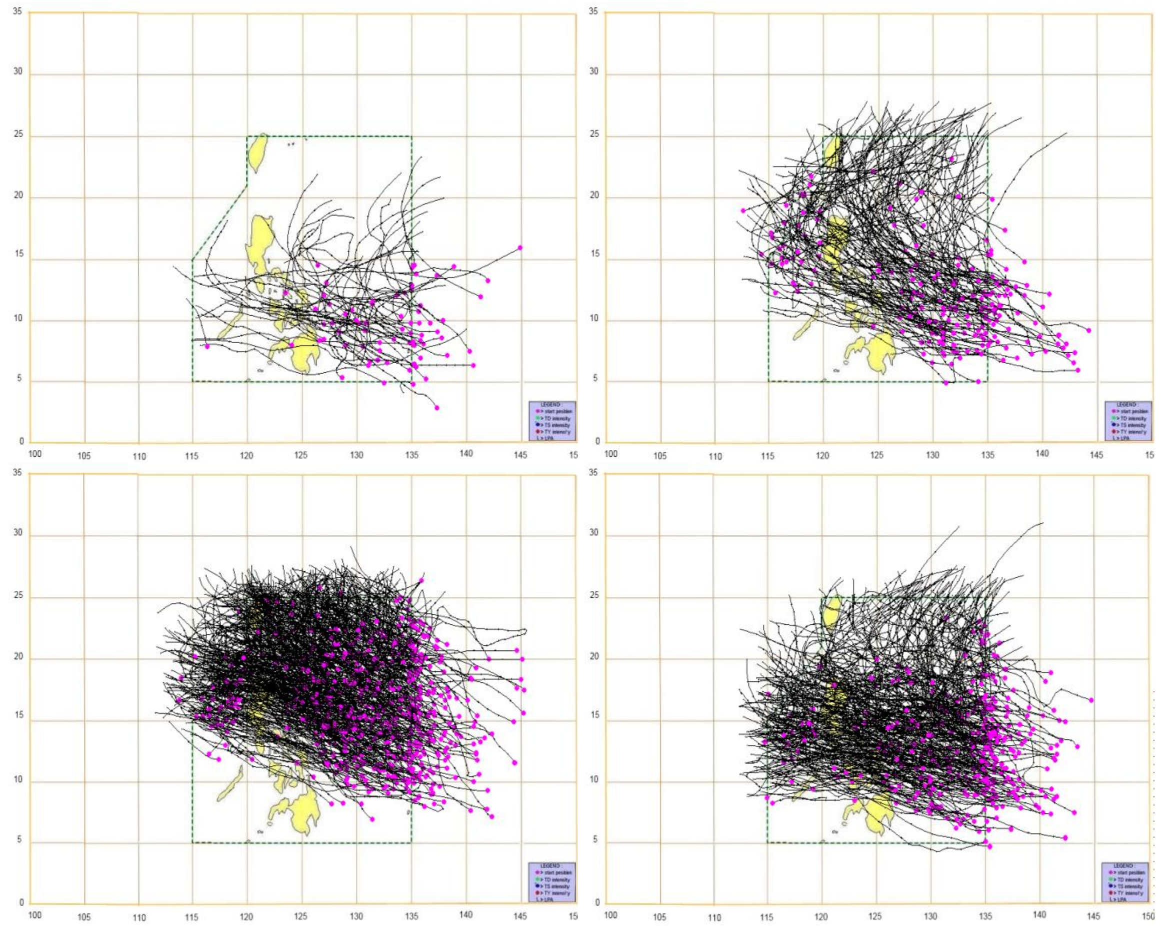


Figure 4. Actual seasonal tracks of tropical cyclones (a) DJF (b) MAM (c) JJA (d) SON from 1951-2013 in the Philippine Area of Responsibility (PAR). Data source: Tropical Cyclone Guidance System (TCGS), Weather Division, PAGASA)

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 increased 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 5 shows the observed trends in mean (a), maximum (b) and minimum (c) temperatures over the Philippines compared with the 1971-2000 normal values.

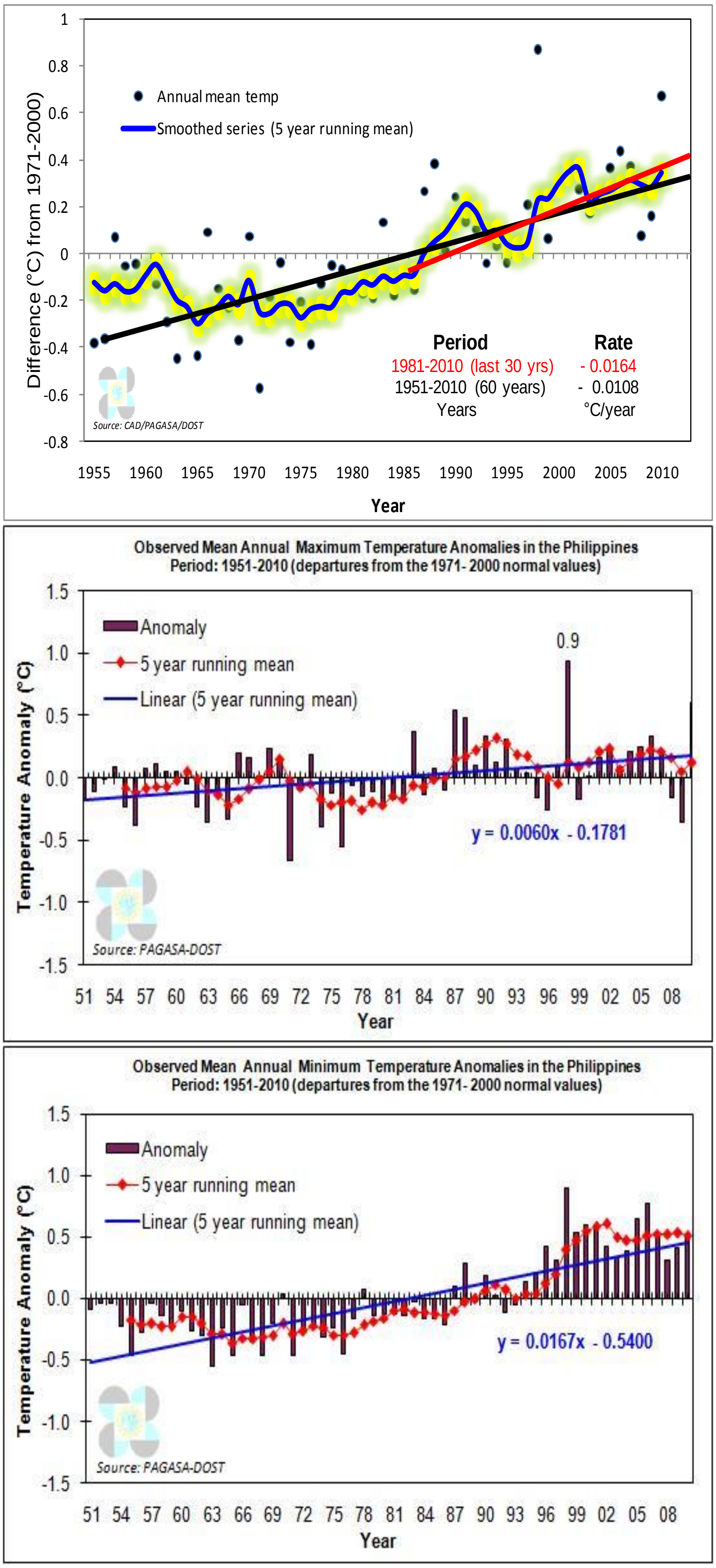


Figure 5. Observed Temperature Anomalies in the Philippines (top to bottom) (a) Mean (b) Maximum (c) Minimum Period: 1951-2010 (departures from the 1971-2000 normal values)

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 2020-2049 and 2050-2079.

Data and Scenarios

The new ERA-Interim (ECMWF Re-analyses Interim) (0.78° x 0.78°) 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 1979-2012 of ERA-Interim was used in Step 1-P2.

The IPCC has developed and used SRES to assess future climate change depicting different assumptions of driving forces of greenhouse gases (GHGs) and sulfur emissions such as population, economics, technology, emissions and land use.

The AMICAF Step 1-P1 used A1B and A2 SRES emission scenarios. The choice of emission scenarios is primarily dependent on the capacity of the Philippines to adapt and mitigate its GHG emissions amidst its current socioeconomic situation and technological advancements. 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. A1B describes a balanced emphasis on the use of both fossil and non-fossil fuel energy source. Meanwhile, A2 describes a very heterogeneous world with high population growth, slow economic development, and slow technological change. Of the two, A2 is considered as high-range emission scenario (or worst case scenario) and A1B is the medium-range emission scenario.

Moreover, three global circulation models (GCMs) which include BCM2, Centre CNCM3, and MPEH5 were also used in Step 1-P1.

The second phase of AMICAF Step 1 used RCP 4.5 and RCP 8.5 mainly because of their similarity with A1B and A2 scenario. RCP 4.5 is the medium-range scenario while RCP 8.5 is the worst case scenario. Figure 6 shows that by the end of 21st century, CMIP5 models project warmer global surface warming compared to CMIP3 models (Knutti & Sedlacek 2013).

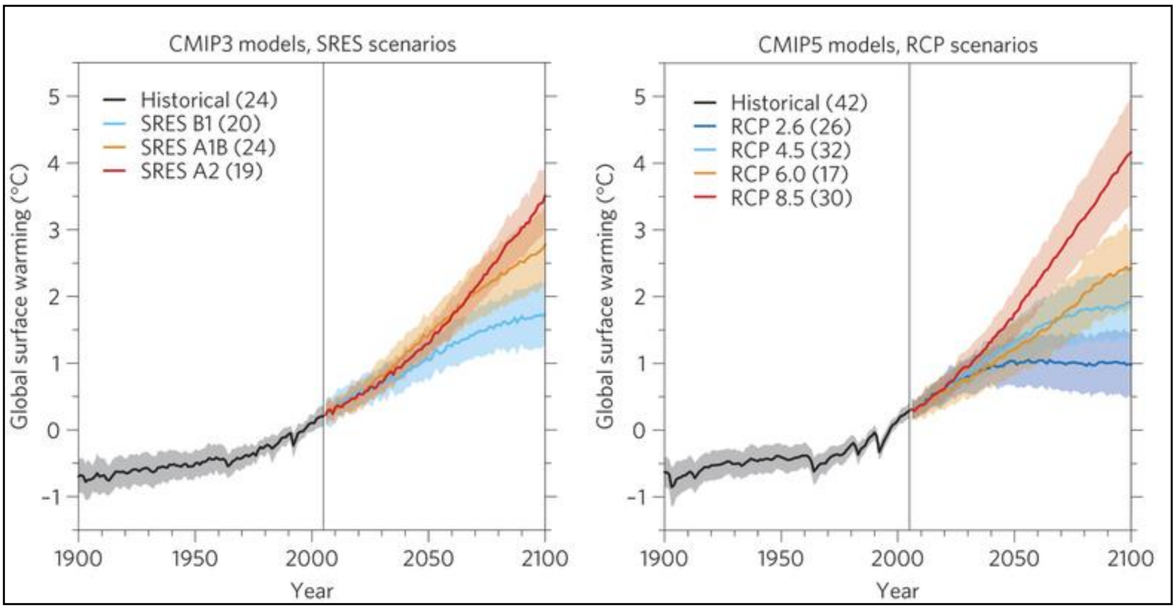


Fig 6. Comparison of global surface warming from CMIP3 and CMIP5 models (Knutti and Sedlacek 2013)

Six ESMs were utilized in statistical downscaling: CanESM2, CNCM5, MPI-ESM, IPSL-CM5, GFDL-ESM2, and MIROC-ESM. In this report, only the first three models will be discussed either as individual ESM or as an ensemble mean or average of the three. There are 47/33/36 PAGASA Stations (precipitation/Tmin/Tmax) employed in statistical downscaling (SD) (Fig. 8) using Generalized Linear Model (Nearest Neighbor) technique for precipitation and the Analogue technique for Tmin/Tmax (Nearest Neighbor).

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.

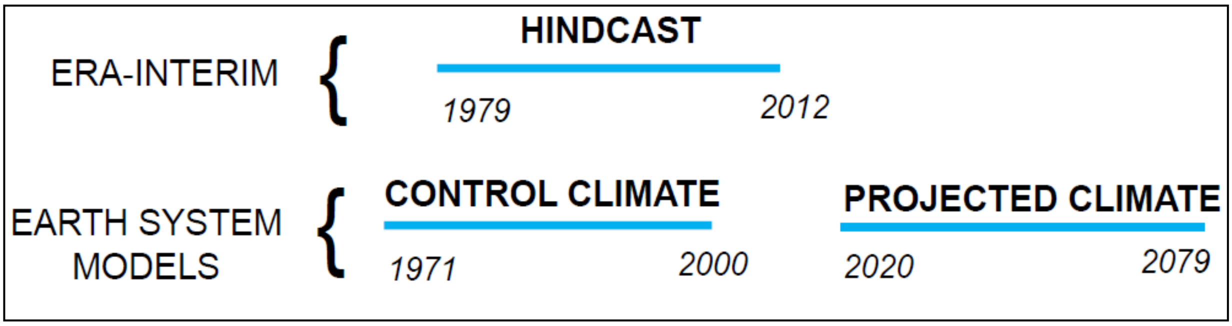


Fig 7. Time slices of different datasets used in SD

Projected changes (2020-2049 and 2050-2079) are relative to the control climate (1971-2000) while ERA-Interim runs from 1979-2012. Baseline years or control climate are also referred to as 20C3M or hindcast (Fig. 7). 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

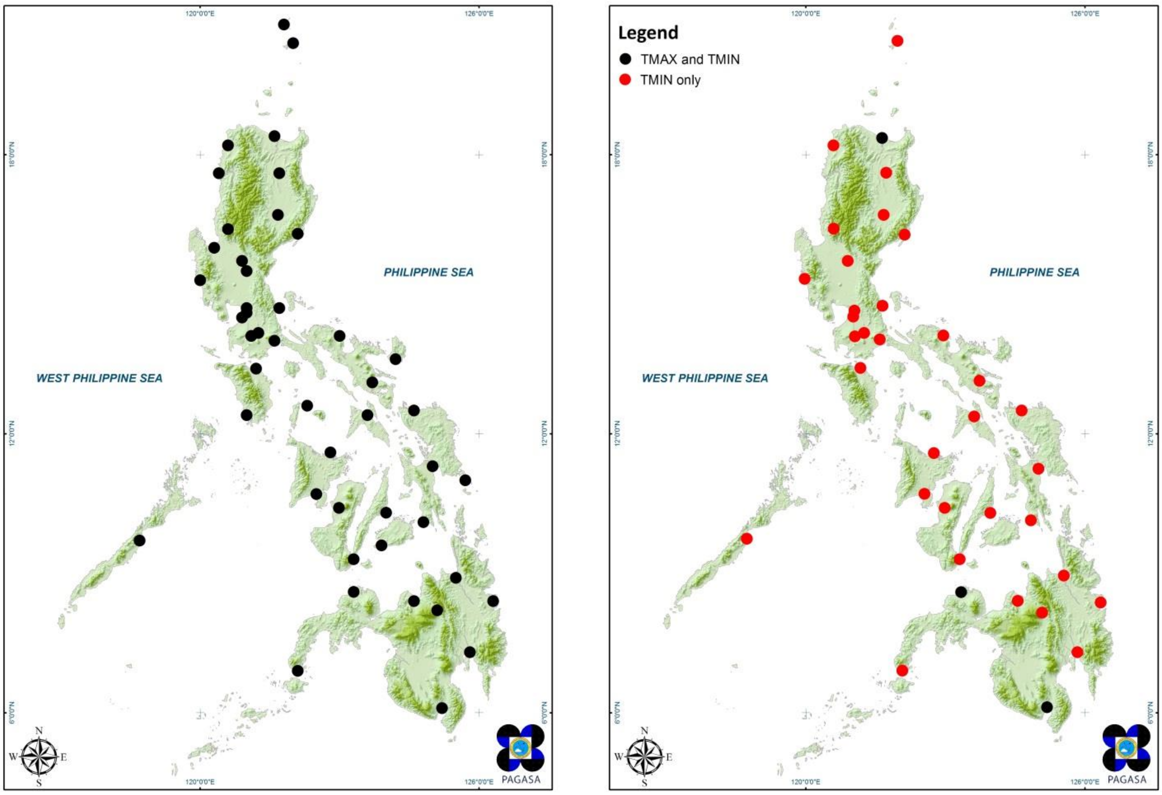


Fig 8. Location of PAGASA Stations used in SD under Step 1-P2

MODEL VALIDATION

Five validation techniques were employed in evaluating the performance of 20C3M (1971-2000) relative to ERA-Interim (1979-2012). These include Pearson's Correlation, Ratio of Variance (RV), Probability Distribution Function (PDF) Score, Mean Absolute Error (MAE), and Root Mean Square Error (RMSE).

Pearson's correlation (R) is used to check the dataset linear correspondence where R=±1.0 indicates perfect positive/negative score. The RV denotes the statistical spread or dispersion of dataset where RV=1.0 means perfect score. Lower RV means highly dispersed distribution of sample points.

Meanwhile, PDF-score is a measure of statistical overlap between dataset where PDF=1.0 means perfect overlap. This is a good indicator of similarity/dissimilarity of dataset values. MAE (Perfect Score = 0) and RMSE (Perfect Score =0) quantify the degree of difference between the two dataset where 0 means no difference or error between the dataset values. Higher error values suggest low performance of models in capturing observed values.

Model Validation: Maximum Temperature

Comparing hindcast and ERA-I, strong positive correlations are calculated in most stations suggesting good dataset correspondence ranging from 0.2 to near perfect score (Fig. 9). Lowest R is computed in Zamboanga Station (R=0.3). RV ranges from 0.4 to 0.8 in most stations suggesting good dataset spread except in some stations in Mindanao (but still within acceptable range). PDF-Score is near 1.0 indicating good overlap of dataset values while statistical errors are within acceptable range.

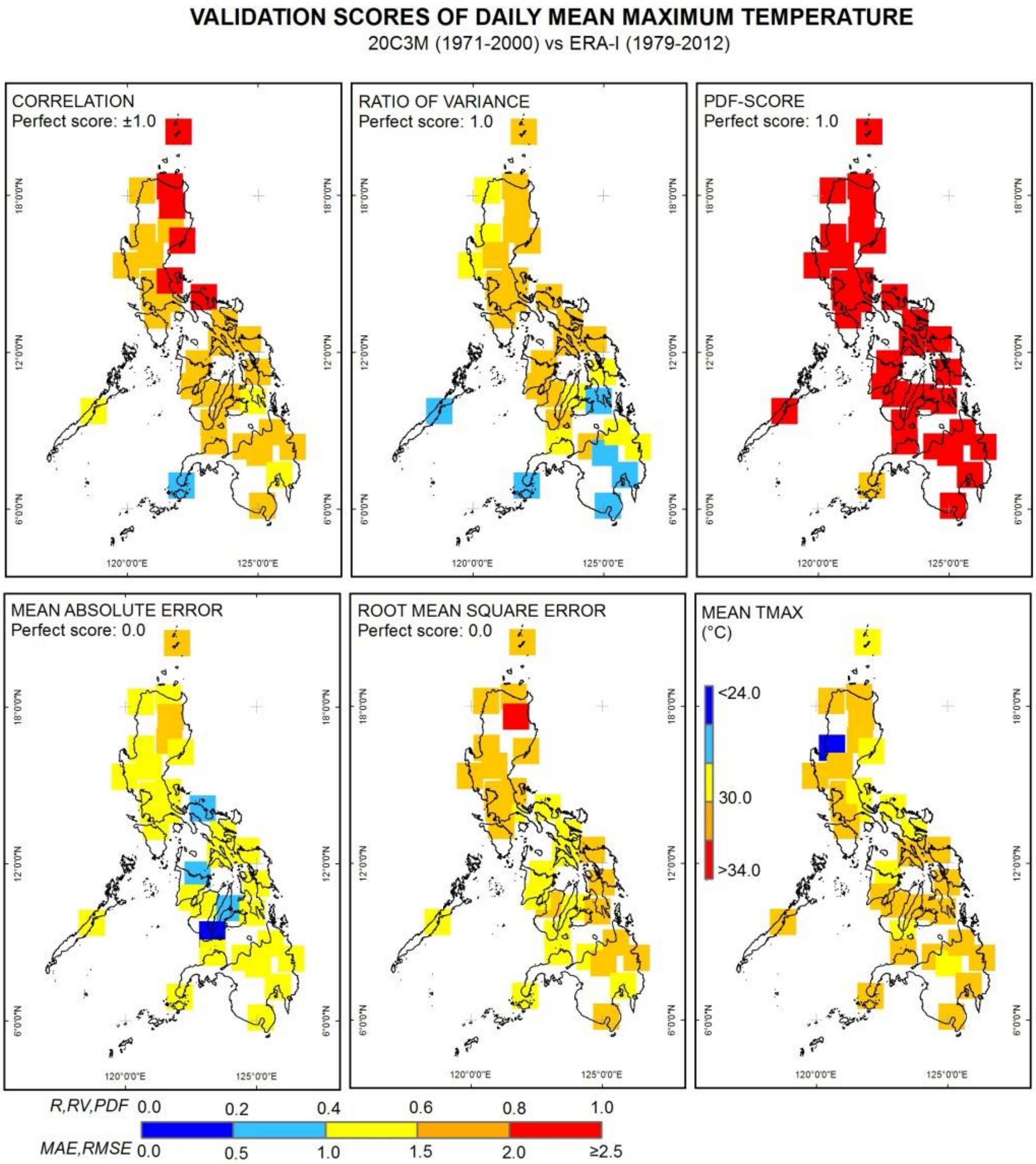


Fig 9. Validation scores of daily mean maximum temperature computed using 20C3M (1971-2000) and ERA-I (1979-2012)

Model Validation: Minimum Temperature

Strong positive correlations are calculated in most stations suggesting good dataset correspondence ranging from 0.2 to near perfect score (Fig. 10). Lowest R is found in Roxas Station (R=0.14). RV ranges from 0.4 to 0.8 in most stations suggesting good dataset spread except in some stations in Mindanao (but still within acceptable range). PDF-Score is near 1.0 in most stations indicating good overlap of dataset values while statistical errors are within acceptable range.

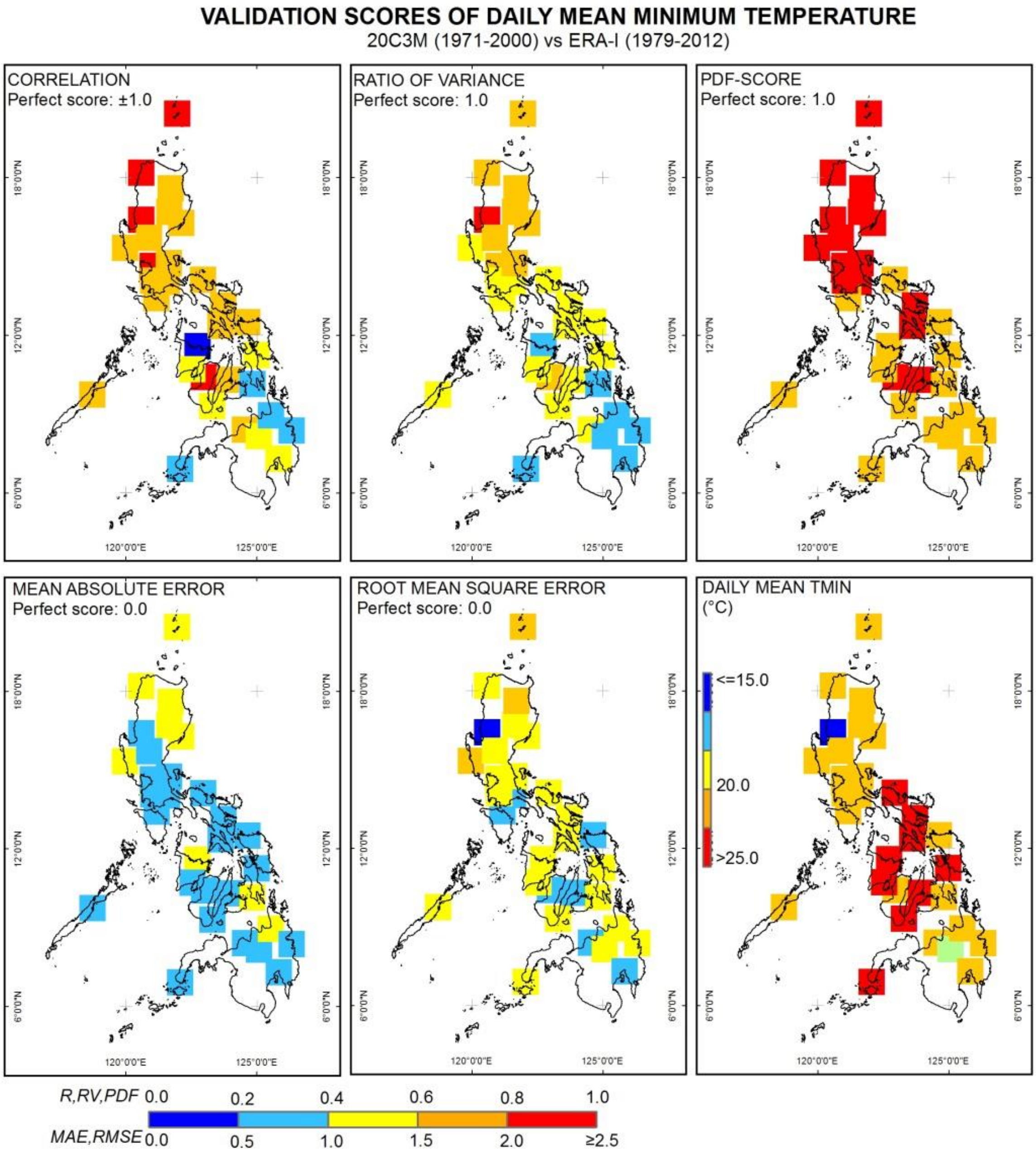


Fig 10. Validation scores of daily mean minimum temperature computed using 20C3M (1971-2000) and ERA-I (1979-2012

Model Validation: Aggregated 10-day Mean Rainfall

Due to high variability of rainfall at daily timescale, the validation was performed using aggregated 10-day rainfall (Fig. 11). Comparing hindcast with ERA-I, strong positive correlations were calculated in most stations suggesting good dataset correspondence ranging from 0.2 to near perfect score. RV ranges from 0.4 to 0.8 in most stations suggesting good dataset spread except in some stations in Mindanao (but still within acceptable range). PDF-Score is near 1.0 in most stations indicating good overlap of dataset values while statistical errors are within acceptable range.

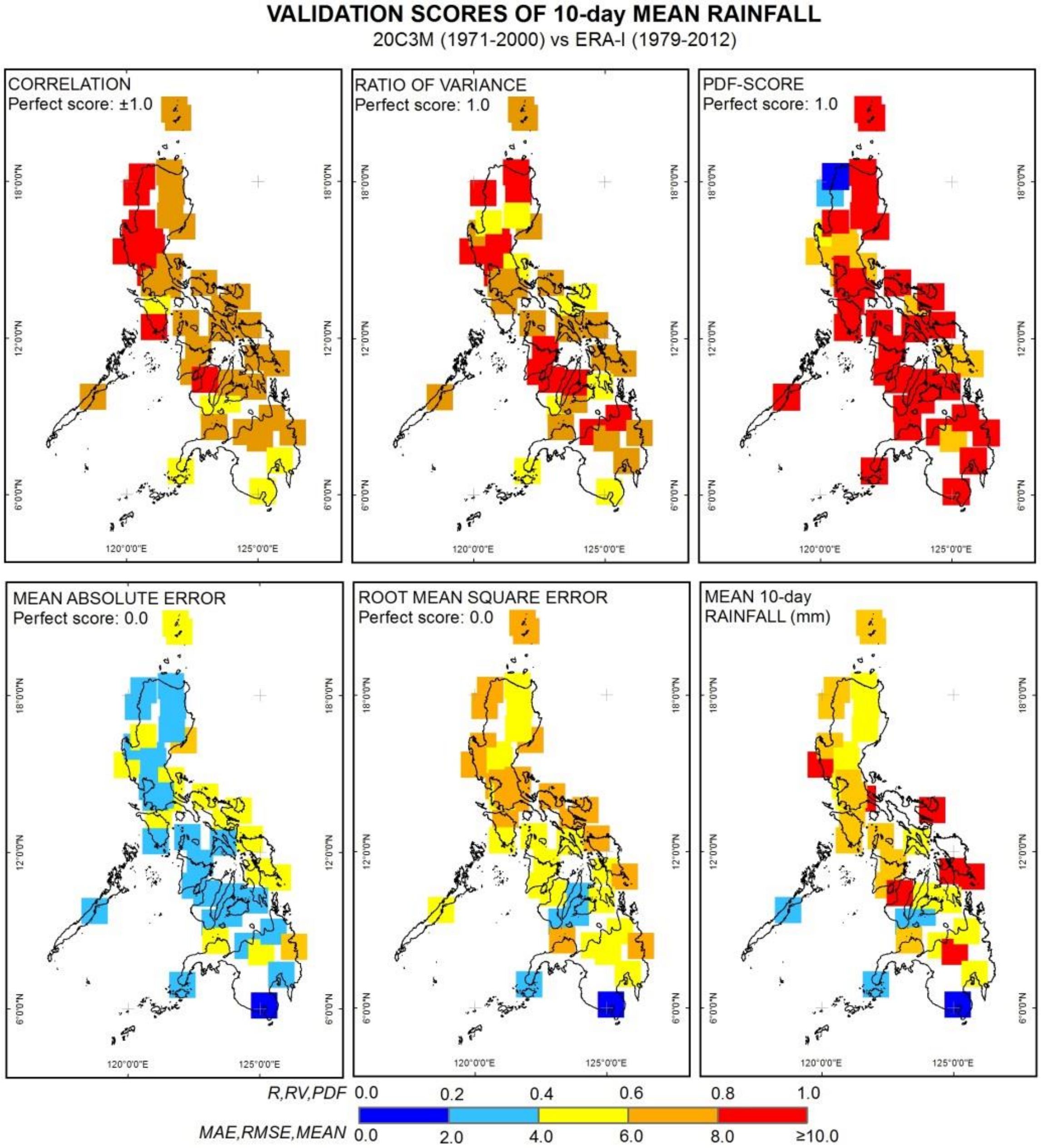


Fig 11. Validation scores of aggregated 10-day mean rainfall computed using 20C3M (1971-2000) and ERA-I (1979-2012)

Projected Changes in Seasonal Maximum Temperature

Figs. 12a to 12d show the projected changes in seasonal maximum temperature under two time periods (2020-2049 and 2050-2079) and under two scenarios (RCPs 4.5 and 8.5. In general, there are projected increases in Tmax in all parts of the country. However, increases are more apparent in cold areas (mountainous Luzon and mountainous Mindanao) which mean these areas will become much warmer than they used to be wherein differences in maximum temperature between lowland and mountainous area will be smaller. On seasonal changes, DJF will be warmer but still cooler compared to MAM where cold areas are projected to have warmer daytime in the future. Highest increase is noticeable for MAM season which suggest warmer days for March April May. For JJA and SON, highest increase is concentrated over Mindanao area.

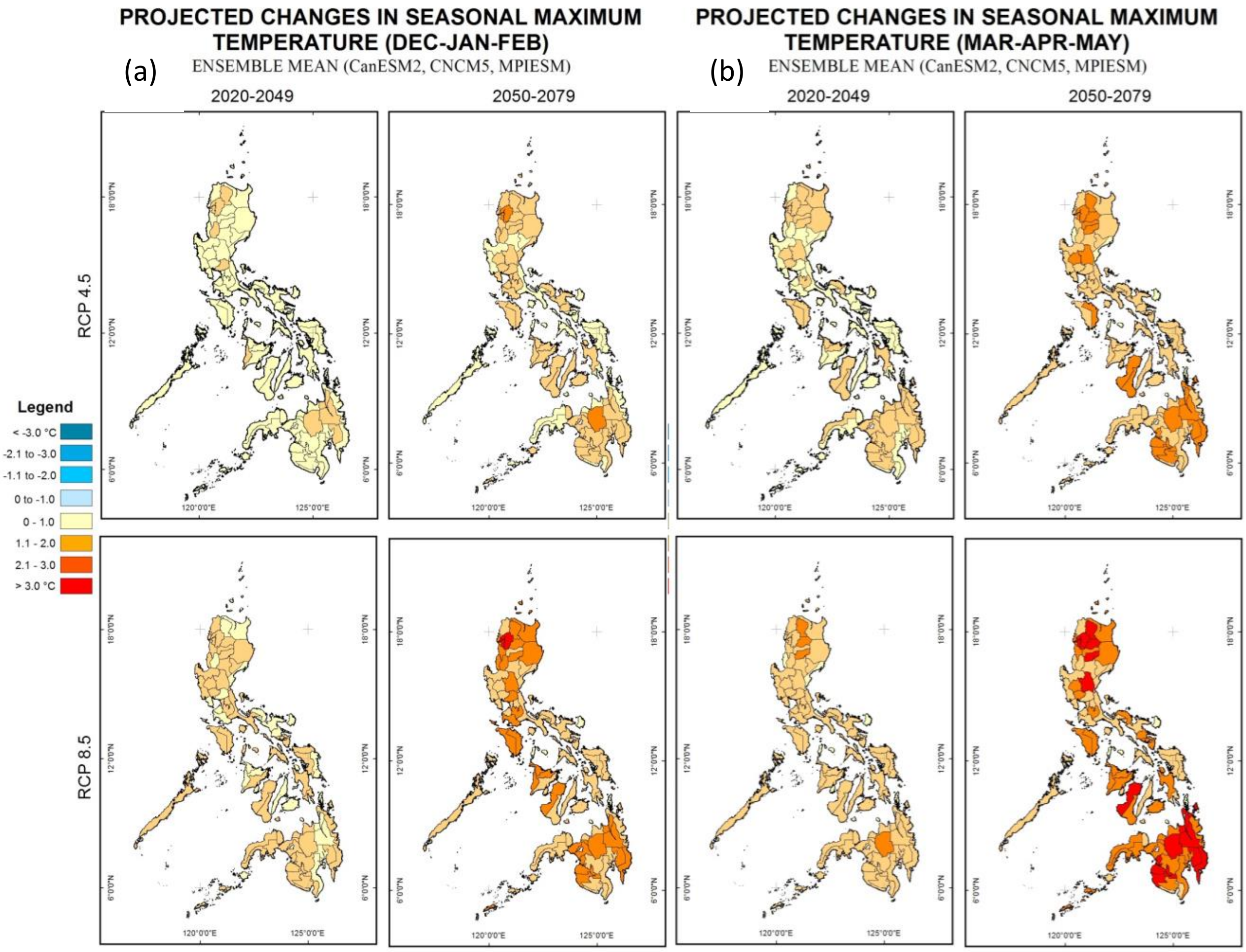


Fig 12. Projected changes in seasonal maximum temperature (L-R): (a) DJF and (b) MAM

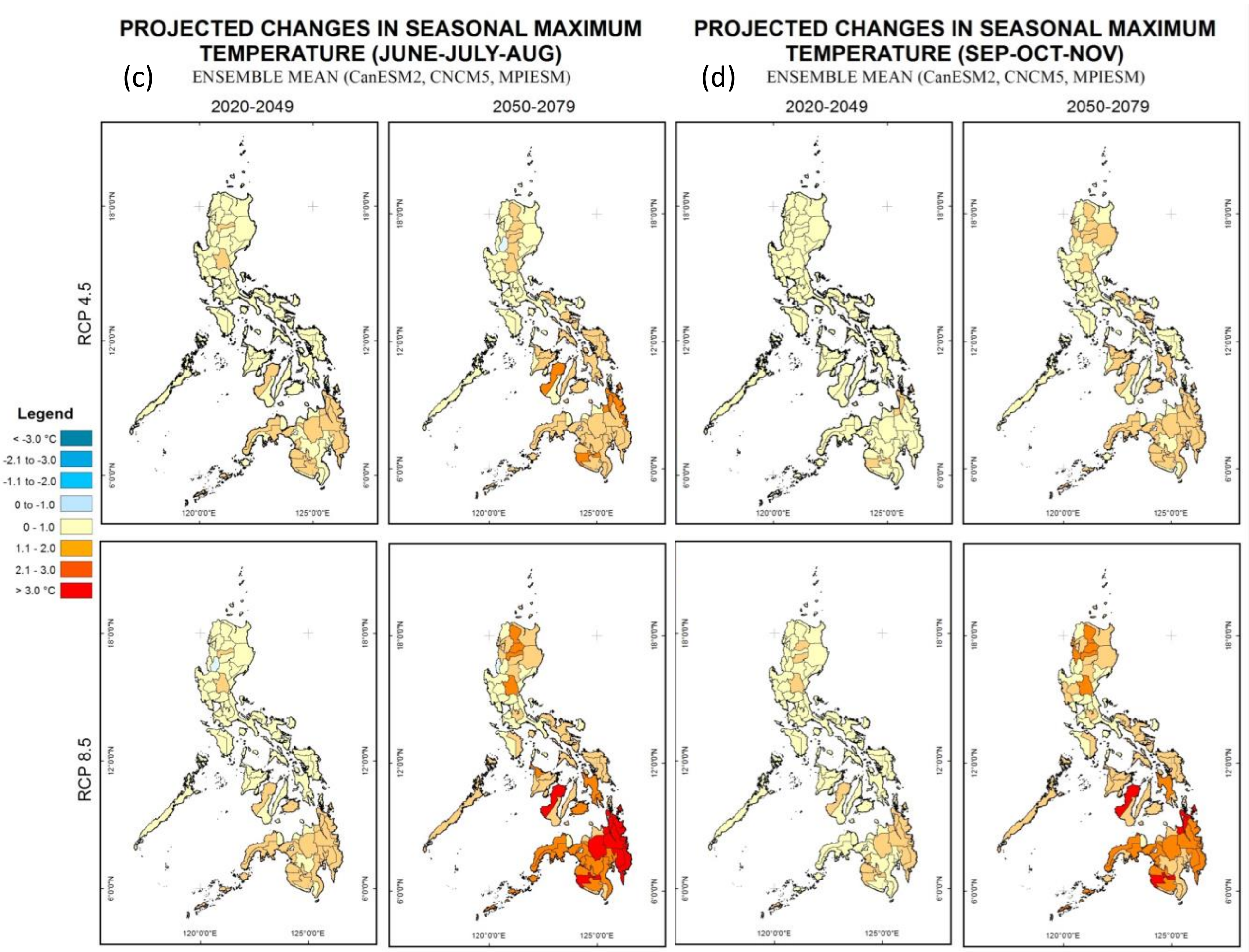


Fig 12. Projected changes in seasonal maximum temperature (L-R): (c) JJA and (d) SON

Projected Changes in Seasonal Minimum Temperature

Figs. 13a to 13d show the projected changes in seasonal minimum temperature of two time periods (2020-2049 and 2050-2079) and under both scenarios. In general, there are projected increases in Tmin in all parts of the country, where increases are most apparent in western seaboard of the country especially in Ilocos Region and some parts of northern Luzon such as Cagayan Valley. All seasons are projected to have increases in Tmin of about 2.0°C indicating that there will be no significant seasonal variability of Tmin in the future. Moreover, MAM is still projected to have the highest increase suggesting warmer nights for March April May.

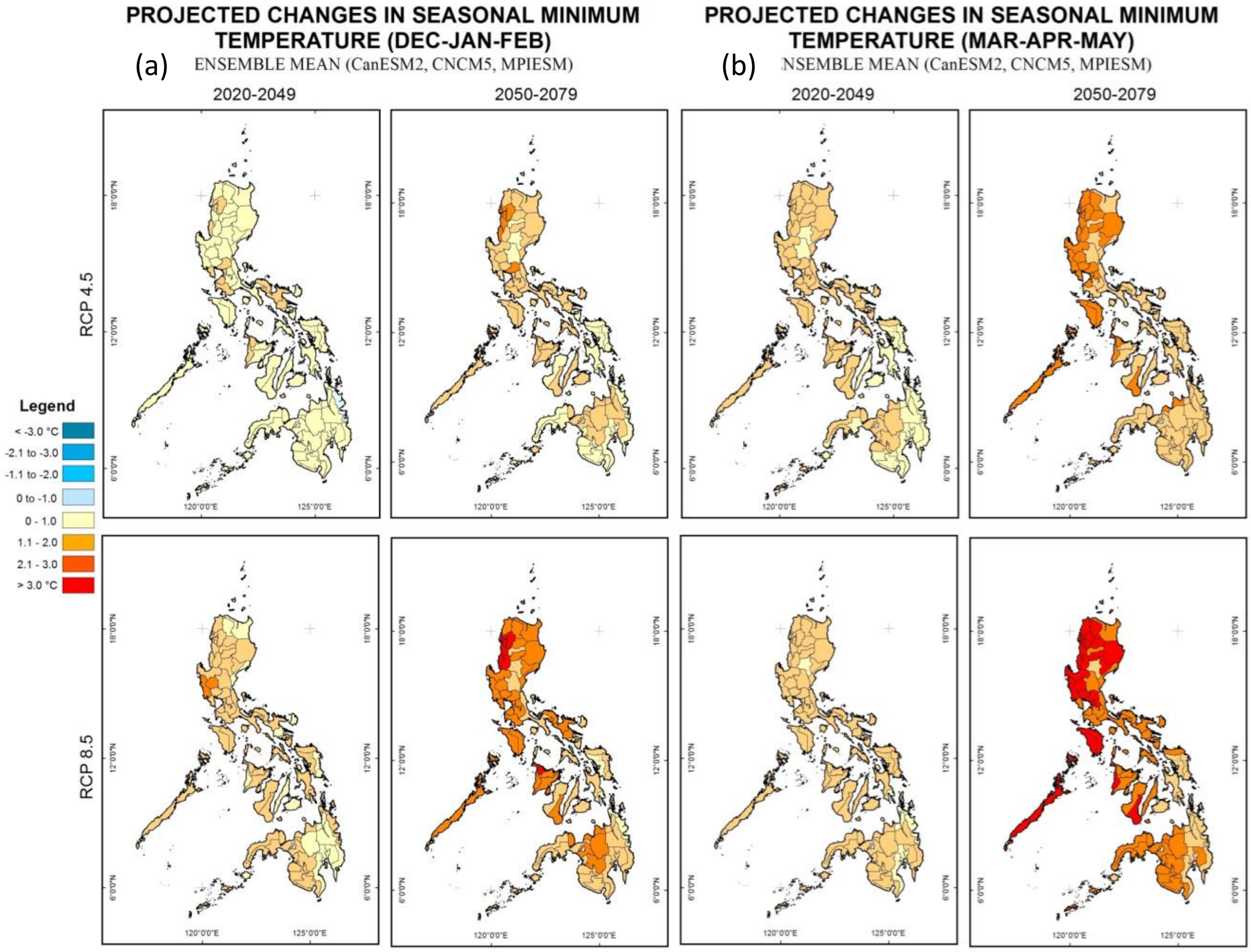


Fig 13. Projected changes in seasonal maximum temperature (L-R): (a) DJF and (b) MAM

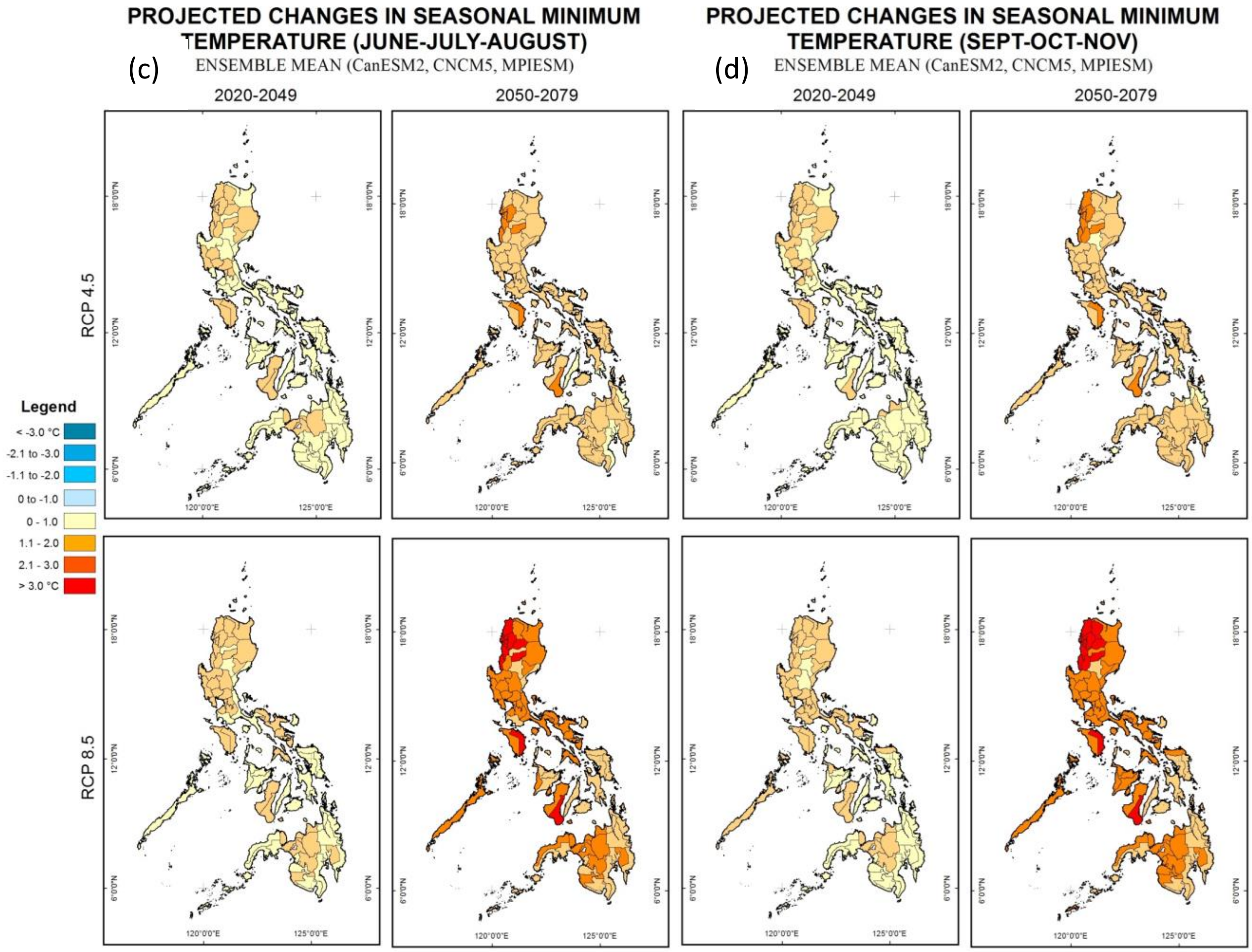


Fig 13. Projected changes in seasonal maximum temperature (L-R): (c) JJA and (d) SON

Trends and Shift in Temperature

It is likely that Tmean, Tmax, and Tmin will increase towards the end of 21st century (2049 and 2079). Tmin, of the three, is likely to have highest increase under RCP 8.5 scenario. This means that, in the future, diurnal variation of temperature will likely become much smaller where daytime and nighttime temperatures will be almost similar. The rate of increase in temperature is approximately 0.02-0.04°C per year.

Figure 14 also illustrates that by the end of 2050, there will be a divergence between RCP 8.5 and RCP 4.5 indicating that the effects of GHG emission from the baseline period (1979-2012) will be more apparent and affect temperature in the Philippines.

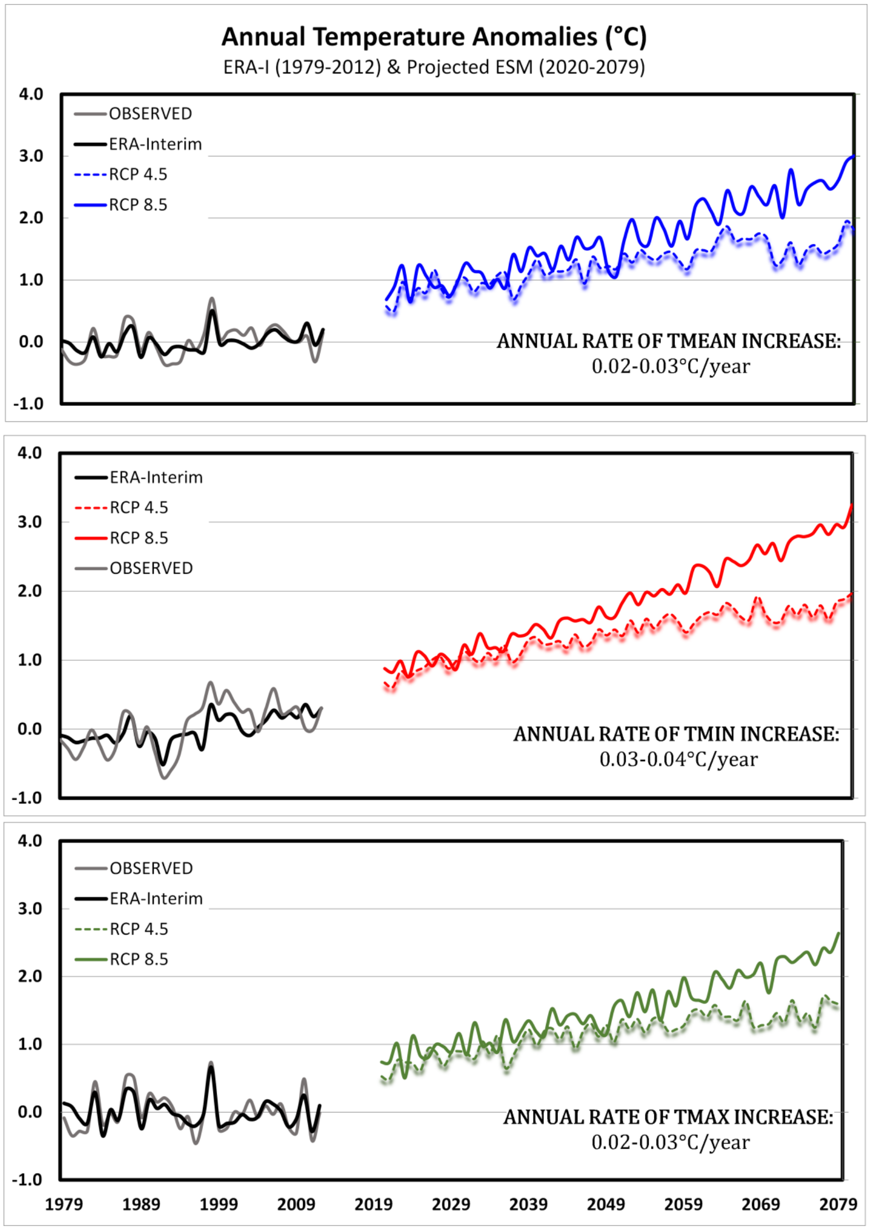


Fig 14. Projected annual temperature anomalies (top to bottom): mean temperature, minimum temperature, and maximum temperature

Figure 15 shows the ensemble mean of Tmin and Tmax under both RCP 8.5 and RCP 4.5 and two time periods. It is likely that distribution of Tmax and Tmin will positively shift 2.0°C above their mean values indicating projected warmer temperature ranges. Frequency of these temperatures has also slightly increased suggesting that warmer temperatures will become more frequent.

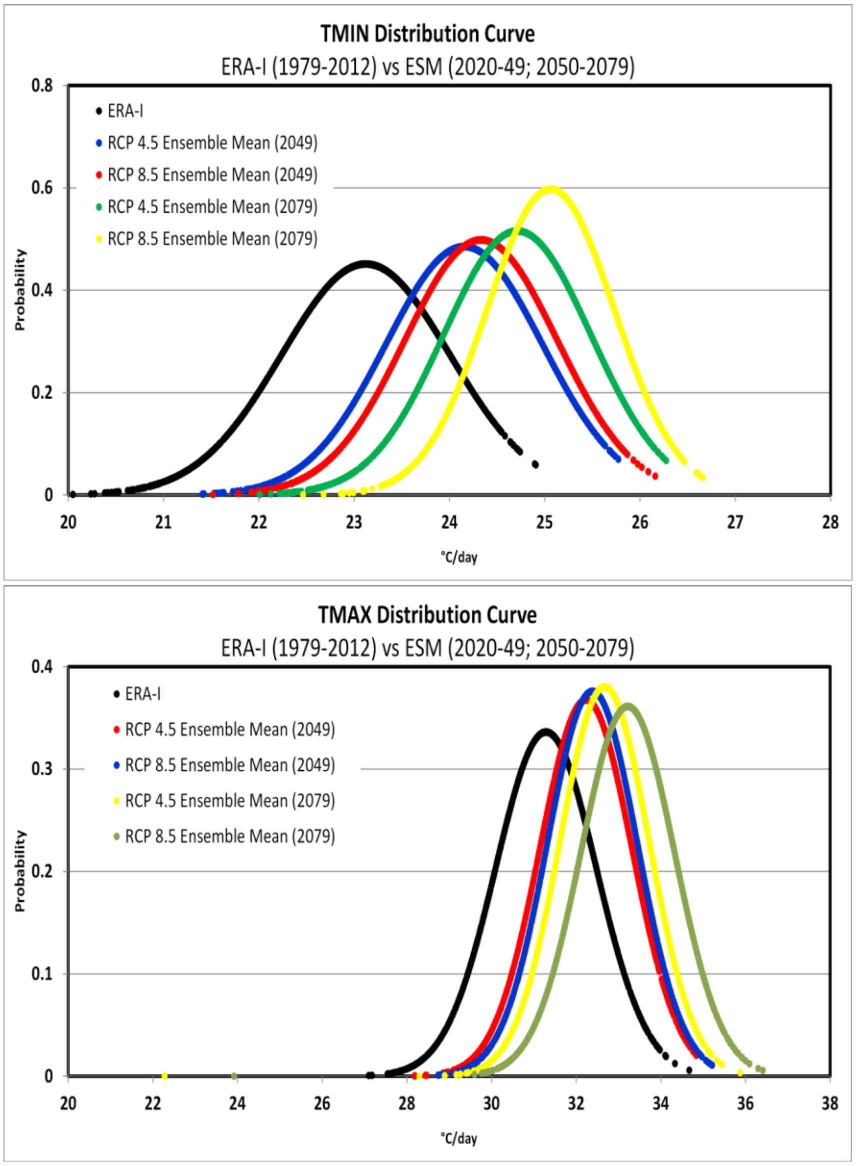


Fig 15. Distribution curve of (top to bottom) minimum temperature and maximum temperature

Projected Changes in Seasonal Rainfall

For both RCPs, an increase in rainfall will be likely observed in both time slices suggesting wetter months for December-January-February season. Least increases in rainfall are perceived in western part of Mindanao. Several studies (Kim, 2005; Jeong, 2011) have noted the decreasing intensity of Siberian High (SH) over the years. This may possibly be the reason why there is projected decreasing rainfall over southeastern Philippines particularly in CARAGA Region. Compared to the rest of the country, provinces in southeastern Mindanao have the lowest projected rainfall increase. If SH will weaken, the rainfall associated with the northeast monsoon will also decrease.

An increase in rainfall is also observed for the whole Country for both RCPs and time slices. Largest increase in March April May rainfall is noted over Luzon area up to 200%. Figure 16c suggests an increase in rainfall for June-July-August season. This conclusion is evident for the period 2020-2049 and further into the future (2050-2079) also suggest higher increase in rainfall (Figs. 16a to 16d)

Increasing rainfall is shown in Figure 16d for September October November. Highest rainfall increase is concentrated over Luzon area in 2020 2049 and 200% increase towards the end of 2079.

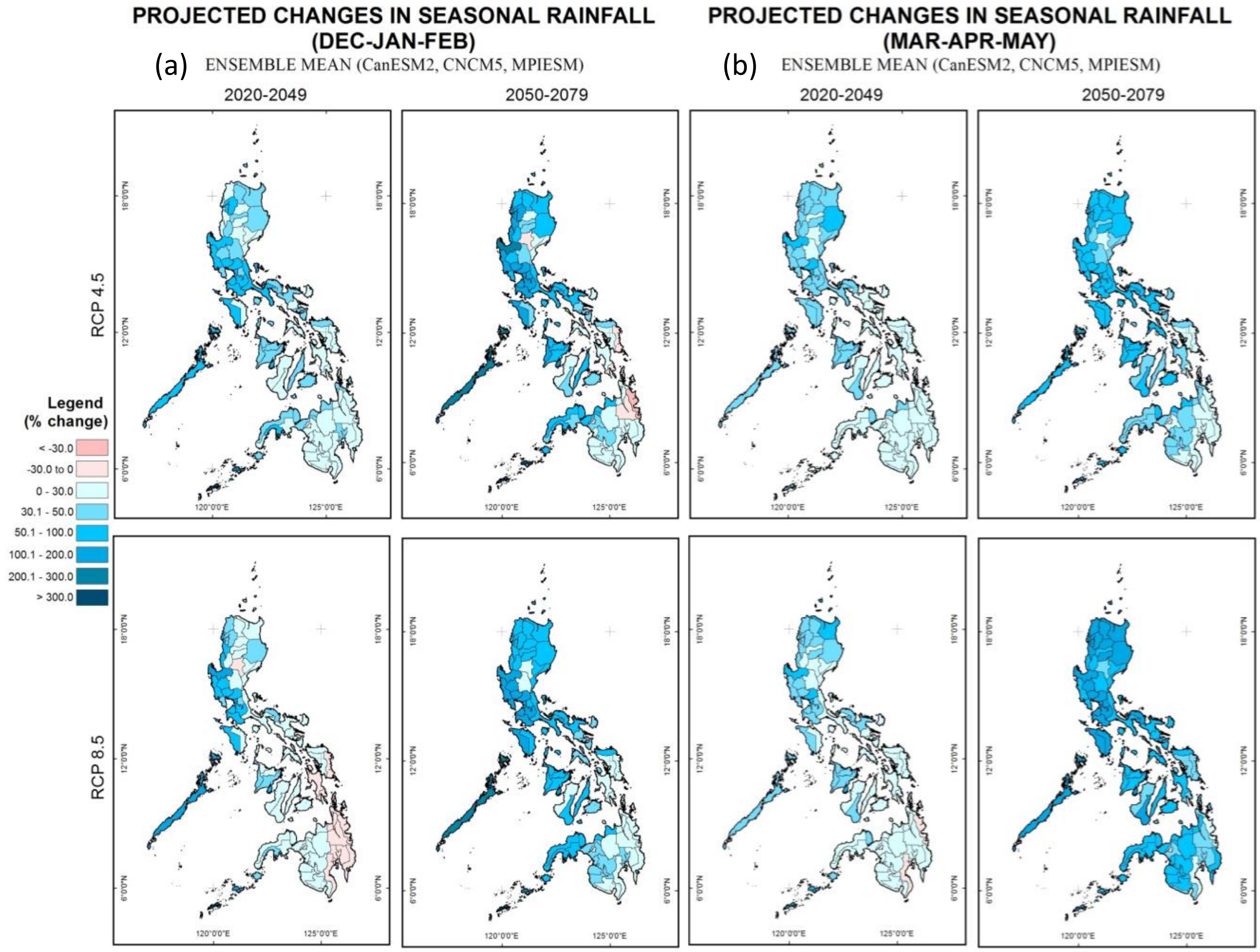


Fig 16. Projected changes in seasonal rainfall (L-R): (a) DJF and (b) MAM

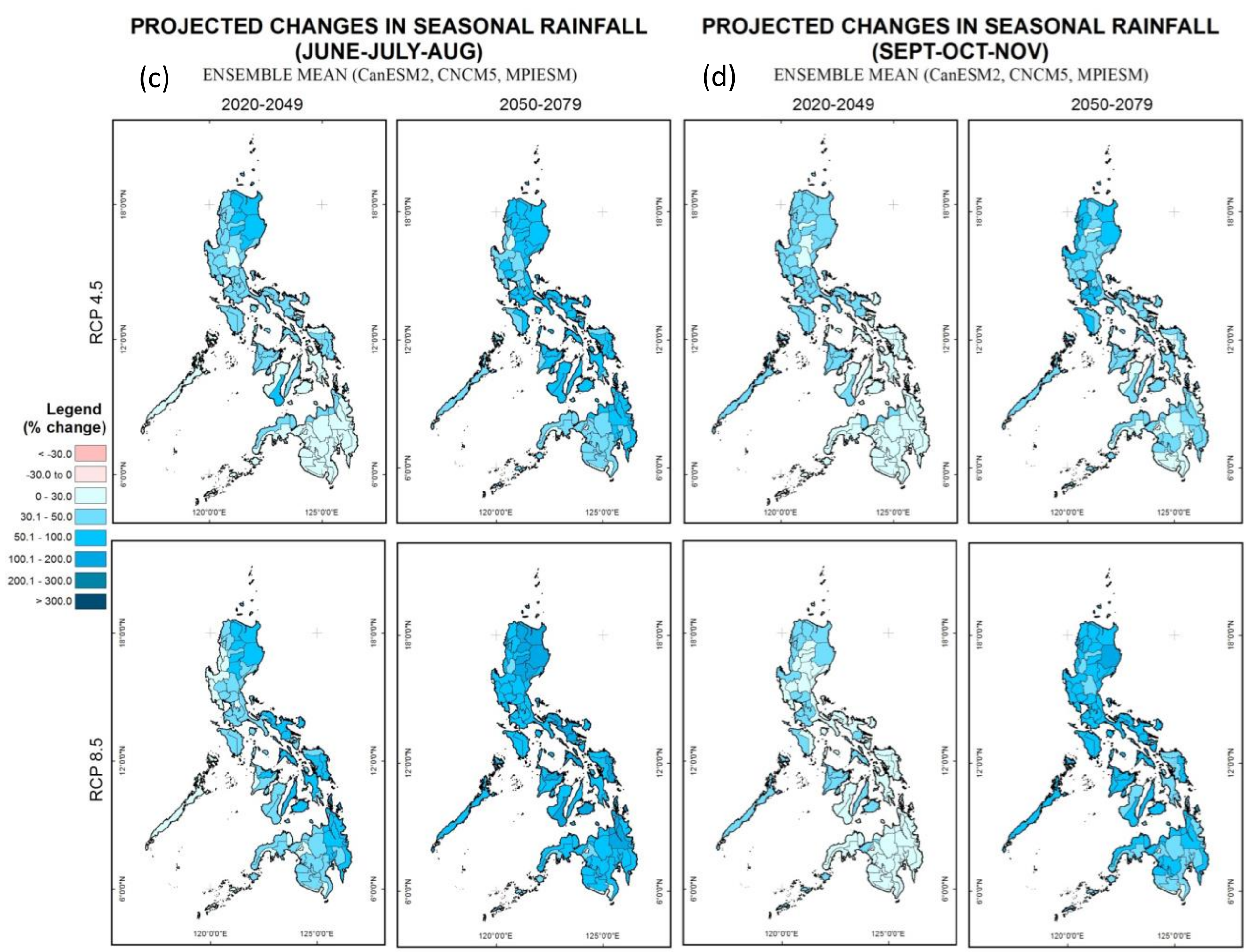


Fig 16. Projected changes in seasonal rainfall (L-R): (c) JJA and (d) SON

Trends and Shift in Rainfall

It is likely that rainfall will increase towards the end of 21st century (2049 and 2079). Luzon, compared to Visayas and Mindanao with 0.1 mm per year, will have higher increase in rainfall by as much as 0.2 mm per year. While this conclusion means that increase in rainfall will be more felt in Luzon than the rest of the country, it is also noteworthy to express that most of the stations used in SD are found in Luzon (Fig. 17), which significantly affect projected results.

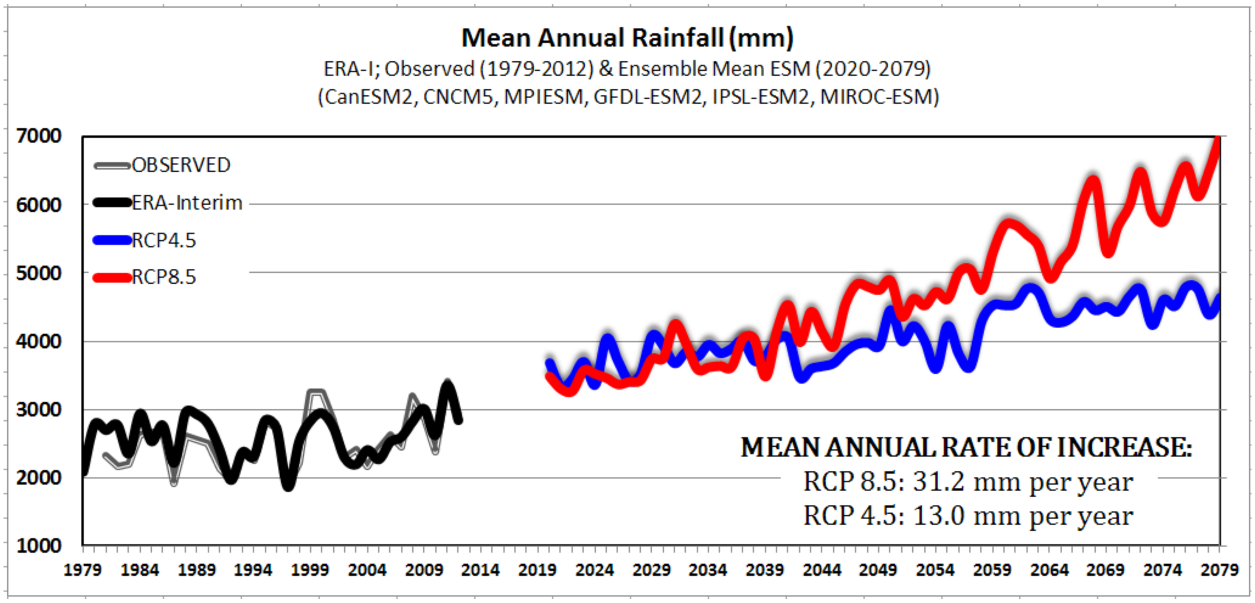


Fig 17. Projected mean annual rainfall (mm) under RCP 4.5 and RCP 8.5

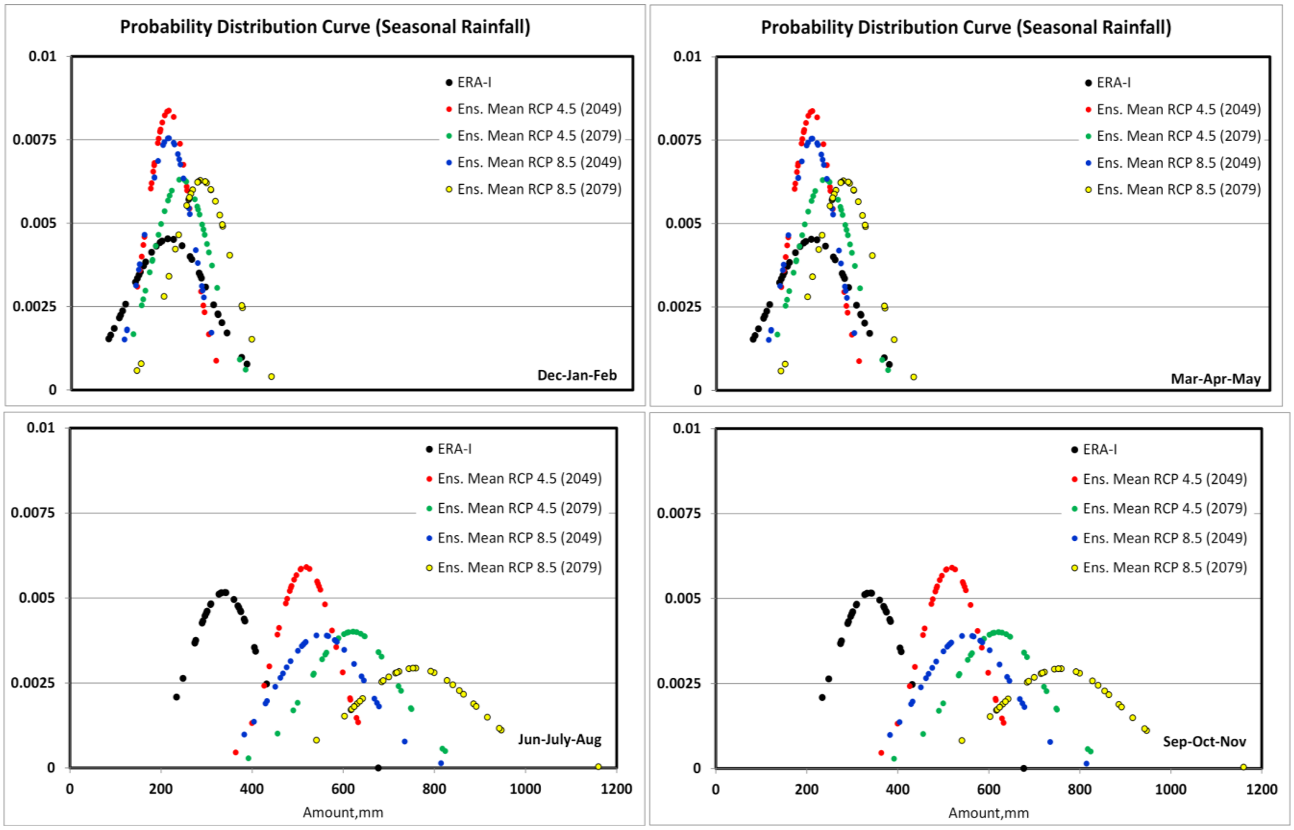


Fig 18. Seasonal distribution curve of rainfall (clockwise): DJF, MAM, JJA, & SON

On seasonal rainfall distribution, it is projected that rainfall in DJF and MAM will become more frequent while rainfall in JJA and SON will become more intense (Fig. 18).

Extreme Nighttime Temperature

Extreme nighttime temperature is defined as a day with minimum temperature greater than or equal to 25°C. Figure 19 shows that there is an increase in the occurrence of extreme nighttime temperature events in Luzon, Mindanao and some parts of Visayas towards both end of 2049 and 2079 under both RCPs while no change to minimal change is projected over Central Visayas. La Granja is projected to have the highest increase in the number of days with extreme nighttime temperature (Table 1).

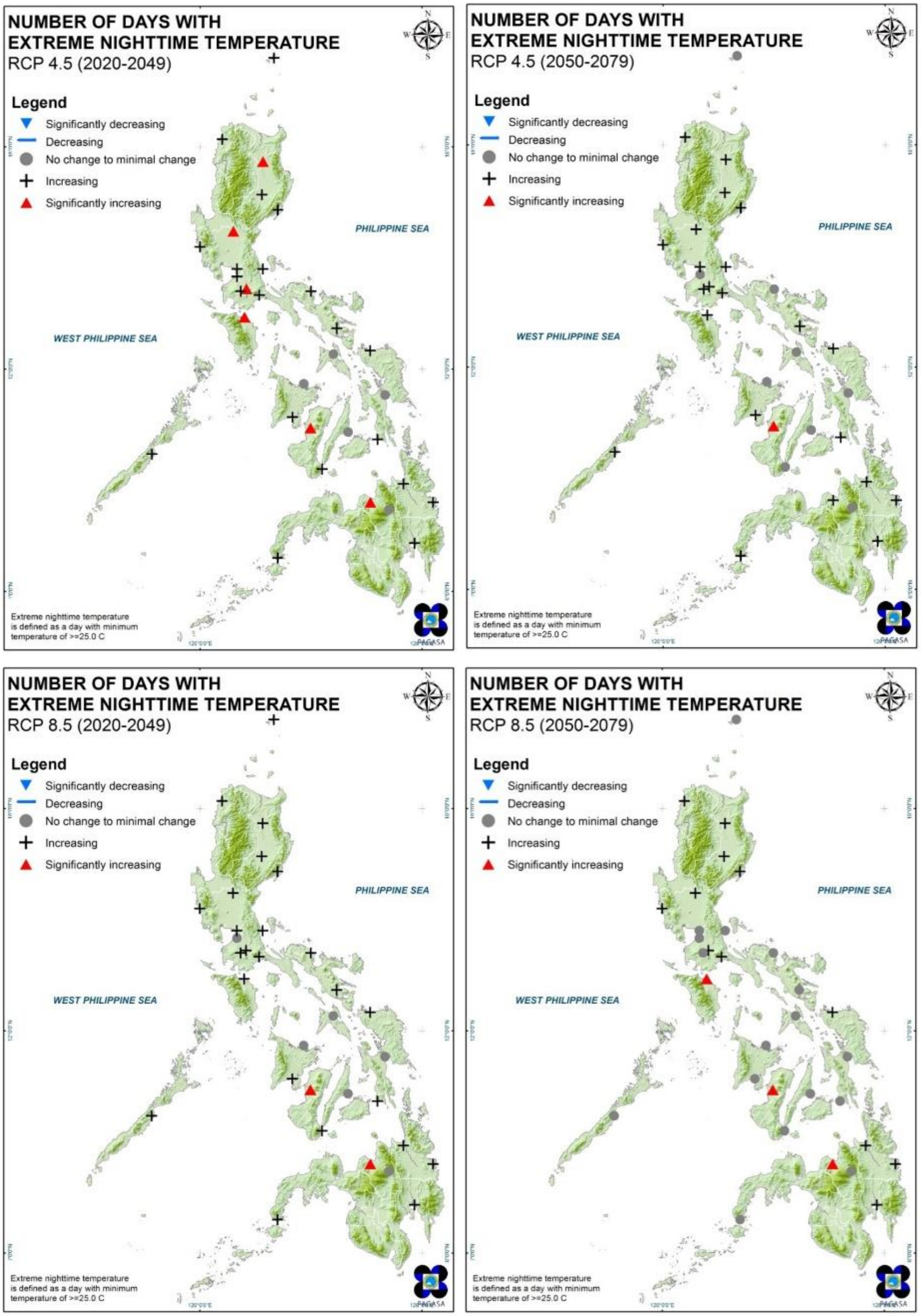


Fig 19. Number of Days with Extreme Nighttime Temperature (top row: RCP 4.5) (bottom row: RCP 8.5)

Table 1. Stations with Highest Number of Days with Extreme Nighttime Temperature Exceeding 25.0°C

RANK	STATION	20C3M	RCP4.5		RCP8.5	
			2020-49	2050-79	2020-49	2050-79
1	*LA GRANJA*	6	2286	2124	1065	5780
2	*LUMBIA AIRPORT*	27	4214	3832	1945	8265
3	*CALAPAN*	132	4577	4151	2576	7441
4	*TUGUEGARAO*	85	2908	2598	1569	4266
5	*MUNOZ*	173	5418	4966	3200	8529
6	*UPLB*	195	5311	4846	3077	7936
7	*TAYABAS*	183	3189	2934	1828	5047
8	*CASIGURAN*	187	2712	2494	1469	5025
9	*IBA*	387	5766	5225	3971	6979
10	*HINATUAN*	254	3649	3333	2213	6825

Extreme Daytime Temperature

Extreme daytime temperature is defined as a day with maximum temperature greater than or equal to 35.0°C. Significant increase in extreme daytime temperature will likely to be experienced over central and southern Philippines (Fig. 20). Considered as the city of extreme temperature, Tuguegarao still ranks as the station with highest projected increase in extreme daytime temperature closely followed by ISU (Table 2). But given the climatological extremes in these stations, they are not considered significant changes.

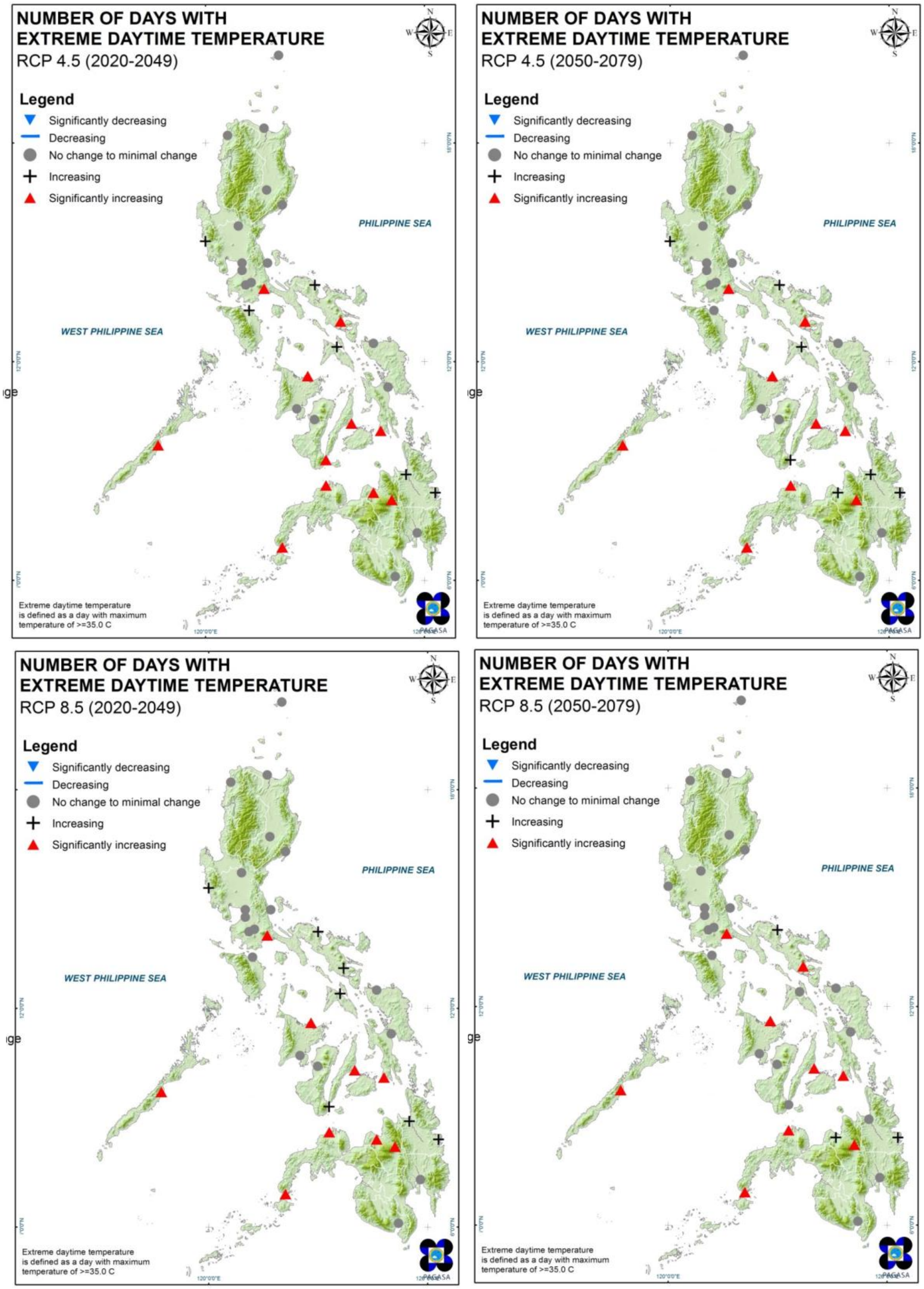


Fig 20. Number of Days with Extreme Daytime Temperature (top row: RCP 4.5) (bottom row: RCP 8.5)

Table 2. Stations with Highest Number of Days with Extreme Daytime Temperature Exceeding 35.0°C

RANK	STATION	20C3M	RCP4.5		RCP8.5	
			2020-49	2050-79	2020-49	2050-79
1	TUGUEGARAO	1968	4019	5021	4433	6475
2	ISU	1563	3128	3933	3464	4869
3	LA GRANJA	1474	2767	3841	3206	5258
4	BUTUAN	269	2414	4463	2909	6496
5	MUNOZ	820	2126	2300	2268	2615
6	SCIENCE GARDEN	764	1888	2030	2009	2424
7	LUMBIA AIRPORT	120	1860	4437	2605	8172
8	AMBULONG	536	1727	2522	2020	3911
9	GENERAL SANTOS	804	1692	2453	1900	3720
10	MASBATE	179	1362	2808	1848	5377

Days with Heavy Rainfall

Days of heavy rainfall are defined as days with greater than 100 mm of rain. An increase in the number of days with heavy rainfall (Fig. 21) is projected on most stations of Luzon while a noticeable decrease in frequency of heavy rainfall days over portions of central Visayas and northern Mindanao. Baguio registered highest frequency of projected rainfall days followed by Iba, and Sangley Point (Table 3). All of which are found under Climate Type 1.

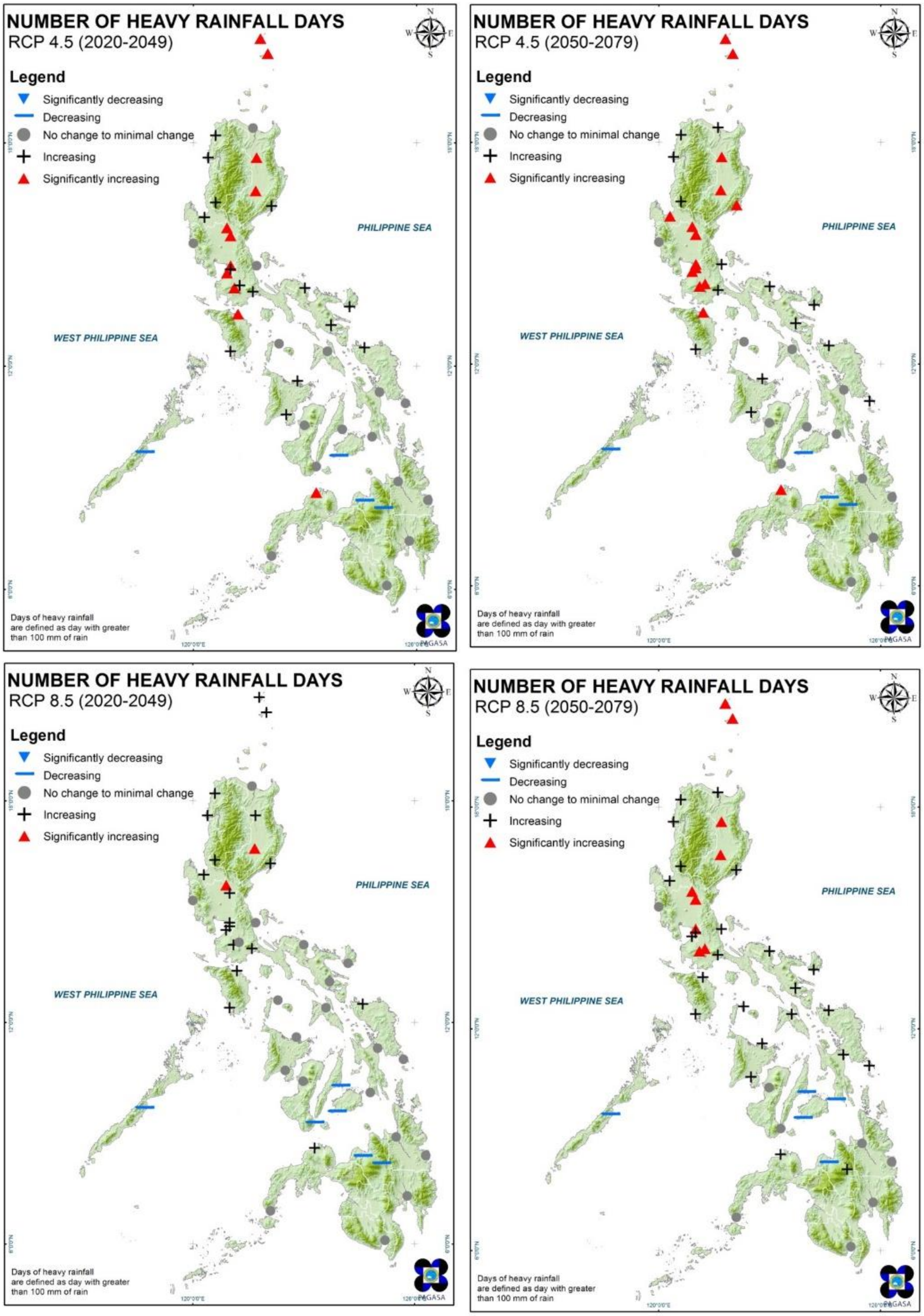


Fig 21. Number of Heavy Rainfall Days (top row: RCP 4.5) (bottom row: RCP 8.5)

Table 3. Stations with Highest Number of Days with Heavy Rainfall

RANK	STATION	20C3M	RCP4.5		RCP8.5	
			2020-49	2050-79	2020-49	2050-79
1	BAGUIO	189	507	474	439	752
2	IBA	250	426	383	381	445
3	SANGLEY POINT	58	316	290	214	366
4	CASIGURAN	64	255	236	181	499
5	SAN JOSE	70	244	220	233	363
6	DAGUPAN	55	214	207	189	397
7	LAOAG	72	172	160	165	405
8	VIGAN	62	171	160	145	258
9	AMBULONG	15	124	113	72	170
10	DAET	35	116	105	67	206

Consecutive dry day

Consecutive dry day is defined as ten consecutive days of less than 1 mm of daily rainfall. An increase in consecutive dry days will likely be experienced in most parts of the country especially in northern Luzon (Fig. 22). In top ten stations with highest number of consecutive dry days are Tuguegarao, Itbayat, Basco, Calapan, San Jose, Infanta, Lumbia, Daet, Davao, and Malaybalay (Table 4).

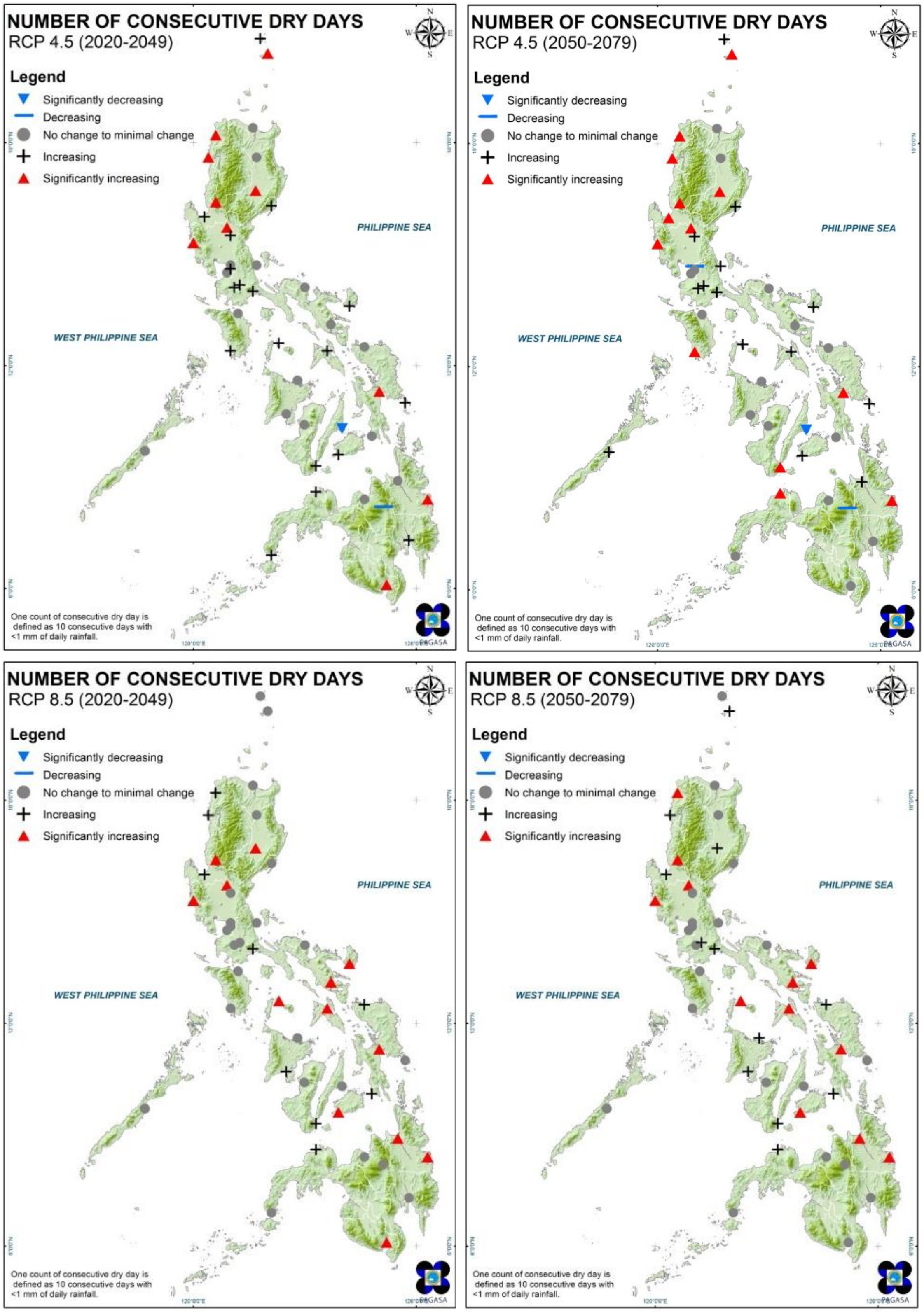


Fig 22. Number of Heavy Rainfall Days (top row: RCP 4.5) (bottom row: RCP 8.5)

Table 4. Stations with Highest Number of Consecutive Dry Days

RANK	STATION	20C3M	RCP4.5		RCP8.5	
			2020-2049	2050-2079	2020-2049	2050-2079
1	TUGUEGARAO	260	271	285	486	485
2	ITBAYAT	201	236	263	466	469
3	BASCO SYNOP	164	226	240	447	469
4	CALAPAN	224	225	217	425	427
5	SAN JOSE	179	215	247	495	484
6	INFANTA	184	209	242	433	442
7	LUMBIA	201	204	232	431	469
8	DAET	182	198	206	453	455
9	DAVAO	144	183	173	360	318
10	MALAYBALAY	212	175	166	414	388

Extreme Events

Figure 23 illustrates a simple mnemonics on understanding changes in both extremes of water availability. If both dry days and heavy rainfall are decreasing then there is low likelihood of extreme events in a particular station. Similar formula could be applied to both increasing dry days and heavy rainfall where drought and flooding are very likely to be experienced/

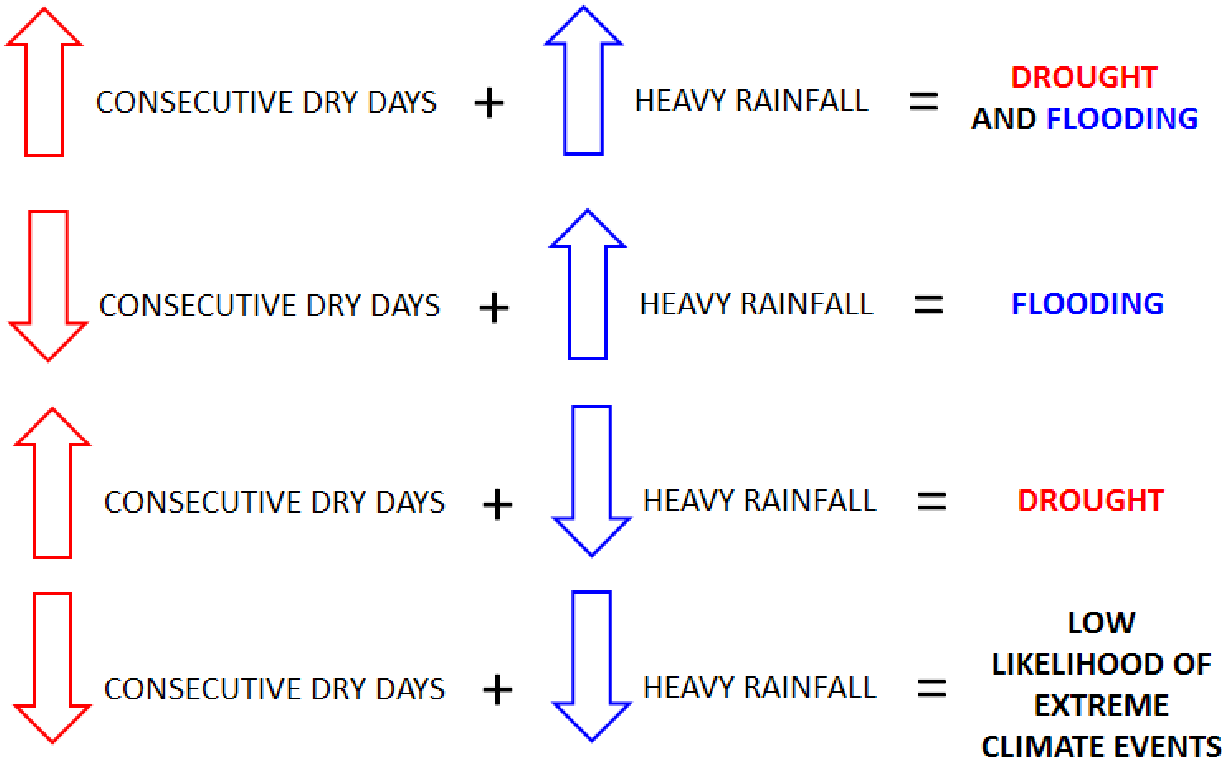


Fig 23. Relationship of consecutive dry days and heavy rainfall days

Conclusions

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 the frequency of heavy rainfall and consecutive dry days, and extreme nighttime and daytime temperatures.

The spatial aggregation of both rainfall and temperature to provincial level is one of the best achievements this project was able to deliver. Analyse Utilisant le RElief pour l'Hydrométéorologie (AURELHY) as an interpolation technique was proven useful in integrating the effects of topography with climatological variables such as rainfall and temperature.

Similar with the results of CMIP3 models (http://www.pagasa.dost.gov.ph/index.php/climate/climate-projection), this project was able to demonstrate that CMIP5 models, through validation scores, several climate projections under two RCPs and two periods.

Directions

We noted significant growth with our project cooperation among institutions especially that computing facilities have already improved. We consider that PAGASA are now more capable both in terms of human resources and technical tools.

Finally, CMIP5 models are being uploaded into PAGASA website to extend data accessibility and its usability. This initiative is expected to be completed in December 2016.

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