IDENTIFYING IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES USING CMIP6 SIMULATIONS: HAVRAN BASIN CASE

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ABSTRACT

IDENTIFYING IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES USING CMIP6 SIMULATIONS: HAVRAN BASIN CASE

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This study aims to investigate climate change effect on precipitation, temperature and discharge in Havran basin which has thousands of decares of agricultural lands. Changes in precipitation and temperature were determined using 10 global climate models (GCMs) for total precipitation and 13 GCMs for average temperature from Coupled Model Intercomparison Project Phase 6 (CMIP6) for the historical period, SSP2-4.5 (moderate-case) and SSP5-8.5 (worst-case) scenarios. Both station observations and ERA5-Land reanalysis datasets are employed for bias correction of the GCM data with Quantile Mapping (QM), Quantile Delta Mapping (QDM) and Detrended Quantile Mapping (DQM) methods. Performance evaluation of bias corrected GCM data is conducted to demonstrate both model and bias correction performance for individual models and ensemble means. QDM and DQM outperform the QM method. QDM method is chosen for further evaluation. The resulting data is employed in GR2M hydrological model for the calculation of monthly discharge. The hydrological modeling is performed for five subbasins of Havran basin with ensemble means and individual models. The resulting precipitation, temperature and discharge were subjected to trend analysis in the historical period (1975-2014), near future period (2015-2044), mid future period

(2045-2074) and far future period (2075-2100) for both scenarios. According to the results, there is an increasing trend in temperature in all parts of the basin for both SSP2-4.5 and SSP5-8.5 scenarios for all future periods where the increase is estimated to be up to 5^{o}C by the end of the century. The worst-case scenario indicates there will be a 120 mm decrease in precipitation by the end of the century. Overall precipitation in the basin is decreasing however changes in the precipitation are not statistically significant. Consequently, discharge in the basin shows decreasing characteristics with up to % 36 decrease by the end of the century in the worst-case scenario.

Keywords: Climate Change, Climate Model, GR2M

ÖZ

İKLİM DEĞİŞİKLİĞİNİN SU KAYNAKLARI ÜZERİNDEKİ ETKİLERİNİN CMIP6 SİMÜLASYONLARIYLA BELİRLENMESİ: HAVRAN HAVZASI ÖRNEĞİ

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Bu çalışma, binlerce dekar tarımsal alana sahip olan Havran havzasında iklim değişikliğinin yağış, sıcaklık ve akımlar üzerindeki etkisini araştırmayı amaçlamaktadır. Yağış ve sıcaklıktaki değişim, Birleştirilmiş Model Karşılaştırma Projesi Faz 6 (CMIP6) modellerinden yağış için 10 küresel iklim modeli (GCM) ve sıcaklık için 13 GCM kullanılarak geçmiş dönem, SSP2-4.5 (orta durum) ve SSP5-8.5 (en kötü durum) senaryoları için belirlenmiştir. Hem istasyon gözlemleri hem de ERA5-Land gözlem verileri, GCM verilerinin Kantil Haritalama (QM), Kantil Delta Haritalama (QDM) ve Trendsizleştirilmiş Kantil Haritalama (DQM) yöntemleriyle yanlılık düzeltmesi için kullanılmıştır. Yanlılık düzeltmesi yapılmış GCMlerin performans değerlendirmeleri hem modellerin hem de yanlılık düzeltmesinin performansını değerlendirme amacıyla yapılmıştır. QDM ve DQM yanlılık düzeltme yöntemleri QM yöntemine göre daha iyi performans göstermiştir. QDM metodu ile elde edilen veriler, aylık akımların hesaplanması için GR2M hidrolojik modelinde kullanılmıştır. Havran havzasının 5 alt havzası için hidrolojik modelleme, topluluk ortalaması ve bireysel modeller ile yapılmıştır. Elde edilen yağış, sıcaklık ve akımlar, geçmiş dönem (1975-2014) yakın gelecek dönem (2015-2044), orta gelecek dönem (2045-2074) ve uzak gelecek dönem (2075-2100) için trend analizine tabi tutulmuştur. Analiz sonuçlarına göre, yüzyıl sonuna dek 5^{o}C kadar artabilecek sıcaklık değerleri tahmin edilen tüm gelecek dönemler için hem SSP2-4.5 hem de SSP5-8.5 senaryolarında havzanın tüm kesimlerinde önemli artışlar göstermektedir. Genel olarak yağışlar azalmaktadır ancak yağışlardaki azalma istatistiksel olarak anlamlı bir trend göstermemektedir. En kötü durum senaryosunda yağışların yüzyıl sonuna kadar 120 mm azalacağı öngörülmüştür. Bunların sonucu olarak havzadaki akımlar en kötü durum senaryosunda yüzyılın sonuna kadar azalan eğilim göstermekte olup bu azalmanın %36 civarında olması beklenmektedir.

Anahtar Kelimeler: İklim Değişikliği, İklim Modeli, GR2M

To my family

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ABBREVIATIONS

CMIP	Coupled Model Intercomparison Project
DQM	Detrended Quantile Mapping
GCM	Global Circulation Model
GDM	General Directorate of Meteorology
GDWM	General Directorate of Water Management
IPCC	Intergovernmental Panel on Climate Change
QM	Quantile Mapping
QDM	Quantile Delta Mapping
SSP	Shared Socioeconomic Pathway

CHAPTER 1

INTRODUCTION

1.1 Introduction

In many regions of the Earth water resources are affected by climate change in terms of quantity and quality. Anthropogenic climate change has exacerbated existing water-related vulnerabilities by influencing physical aspects of water security, such as increased water scarcity and an increase in the number of extreme events such as floods and droughts. The hazards associated with water and changes in water availability can be directly attributed to anthropogenic climate change. The current state of warmer and drier conditions has caused economic losses to be high in sectors directly related to climate such as forestry, fisheries and energy, including agriculture. (IPCC, 2022)

In the lands surrounding the basin, water reaches the water bodies to which the basin is connected through the surface flows that occur as a result of many complex interactions within the hydrological cycle. Understanding the changes in surface flow in a basin depends on how well the processes in the water cycle are understood by taking anthropogenic impacts into account. (Winter et al., 2016)

Mean surface temperature values in the last 10 years have reached a level that is defined as the hottest centennial scale range reconstructed for the present interglacial period. Consequently, increasing evapotranspiration rates and decreasing precipitation are expected to change the quantity of the renewable water resources such as surface and groundwater. Discharge in the scale of basins under changing climatic conditions must be well understood for the sustainable planning and management of water resources. (Guo, et al., 2022)

In an irrigation-dominated basin, sustainable water management seeks to ensure a long-term, adaptable and stable water supply to meet crop water demand while reducing environmental impacts. It is critical to understand basin hydrology for the assessment of water quality and quantity affected by rapid urbanization and land use changes. (Anand, Gosain, Khosa, & Srinivasan, 2018)

The variability within the climate cannot be explained through a straightforward theory therefore climate models have been developed by many institutions. The Coupled Model Intercomparison Project (CMIP) has been developing climate models for over 20 years under World Climate Research Programme – Working Group on Coupled Modelling (WGCM). While the 2013 IPCC 5th assessment report shaped CMIP5, the 6th Assessment Report (AR6) features the CMIP6 models. CMIP has become a foundational element of climate science by coordinating the design and distribution of global circulation model simulations of the past, present, and future climate. CMIP collects global coupled ocean-atmosphere general circulation model outputs that are used to detect anthropogenic effects in the past century's climate record and to project future climatic changes caused by human production of greenhouse gases and aerosols (Eyring, et al., 2016).

The main cause of current and future climate change is anthropogenic increases in the concentrations of atmospheric greenhouse gases. Within the scope of the IPCC AR6 studies, SSP scenarios representing each future socio-economic projection and political environment were created. (Meinshausen et al., 2020) In the IPCC AR6, a new set of emission scenarios were developed depending on different socioeconomic assumptions which are called Shared Socioeconomic Pathways (SSPs). They are referred to as SSP_{x-y} in which SSP_x is the Shared Socioeconomic Pathway describing the socioeconomic trends that sets the basis of the scenarios and y is the radiative forcing in W m^{-2}. In this study, SSP2-4.5 and SSP5-8.5 scenarios are employed. SSP2-4.5 scenario is referred to as "Middle of the road" scenario. CO_2 emissions are estimated within the current levels and beginning to decline by the mid-century. Under this scenario temperature increase by the end of the century is expected to be 2.7^{o}C on a global average. SSP5-8.5 scenario is the worst-case scenario and current

CO_2 emissions are nearly doubled by the mid-century. Temperature change on the global average is expected to be around 4.4 ^{o}C. (IPCC, 2022)

In comparison to CMIP5 and CMIP6 radiative forcing scenarios, new SSP based scenarios also have economic and social aspects for assumed emission pathways and changes in land use as different than RCP scenarios. In addition, historical greenhouse gas and aerosol emissions with the incorporation of land use changes and the use of integrated assessment model utilization make SSP scenarios an upgraded version of RCP scenarios. (DKRZ, Deutsches Klimarechenzentrum, n.d.)

Climate change projections are essential for planning adaptation strategies, especially since GCMs are the most accurate tools for predicting climate change. Although uncertainties remain in climate change projections, it is important to take into account the wide range of simulation results. (Shiogama et al., 2021)

It is important to understand the effects of climate change on hydrological systems for the management of water resources, flood risk control and protection of ecology. Evaluations to understand these effects are made by integrating the future values of climate variables such as precipitation and temperature outputs of climate models into hydrological models. (Meresa, Bernhard, & Tewodros, 2022)

In this study CMIP6 GCM outputs are employed using three different quantile mapping bias correction methods in the post-processing of Raw GCM data and their performances are evaluated. The best performing method is chosen for predicting the changes in total precipitation, mean surface temperature and monthly total discharge within Havran basin.

1.2 Objectives of the Study

Havran Stream is located on the southern slopes of Ida Mountains in Balıkesir province, and the streams on the western and northern slopes of Madra Mountain. Havran Dam was built on the Havran Stream to provide irrigation service to an area of 3060 ha (Cebe & İnan, 2020).

With the construction of Havran Dam that started on June 1995, an issue related to the ecological importance of the basin emerged regarding flora and fauna species inhabiting the İnboğazı caves. The area is sensitive to climate change and its impacts considering the ecological diversity of the region. Also, agricultural activities in the region dominate economical activities. Climate change-induced changes in the temperature, precipitation and discharge have direct impacts on agriculture. Therefore, it is important to estimate the impacts of climate change on those parameters. In order to do so, climate change impact studies need to be updated with the latest climate models.

The objectives of the study are to assess the performance of different quantile mapping based bias correction methods, to identify the performance of individual GCMs and ensemble models and to evaluate changes in precipitation, temperature and discharge within the Havran basin to reach the goal of to update the climate change effect studies on water resources of Havran basin using the latest climate models.

In this study, future changes in the water balance in the basin are estimated by examining temperature, precipitation and discharge under two different scenarios of the most recent earth system models developed for the upcoming IPCC 6th Assessment Report. In this way, this study differs from previous studies conducted within the region.

1.3 Literature Review

The hydrological cycle must be represented by climate models in order to understand future climate scenarios. The coupling of climate model output and appropriate hydrological model is essential to do so. However, systematic biases naturally exist within the model data must be preprocessed before the data extracted from the model can be employed in hydrological model. In order to eliminate the biases, statistical bias correction methods were developed. (Heinke, Dieter, & Piani, 2011) Given the systematic errors of climate models, their output is often not directly applicable as input for hydrological models. (Hagemann et al., 2011)

Eden et al. (2011) stated that the ability of GCMs to describe observed precipitation is increased when the GCM data is post-processed with a statistical correction which can include a downscaling component (Eden et al., 2012). The Quantile Mapping (QM) method shows better performance in comparison with other simpler bias correction methods for precipitation data, particularly with the large amounts of quantiles (Themeßl et al., 2012). Canon et al. (2015), suggested that the QDM bias correction method that outperforms the traditional QM method explicitly preserves relative changes in all of the quantiles within the precipitation data distribution. The study of Kırdemir & Okkan (2019) has supported that by investigating Quantile Mapping, Equiratio Quantile Mapping, Detrended Quantile Mapping and Quantile Delta Mapping bias correction methods separately and evaluating their performances with several performance indices. According to their findings, QM method gave the larger errors among all bias correction methods. Also, it was found that QDM method was superior in comparison to other bias correction methods (Kırdemir & Okkan, 2019).

In the study of Bağçaci et al. (2021) CMIP5 and CMIP6 outputs are evaluated for each available model in terms of the ability to simulate precipitation and temperature in different regions of Turkey. It was shown that CMIP6 models perform better than CMIP5 models. Also, the best performing models are ranked depending on several performance metrics and top 4 models for each precipitation and near surface temperature variables are employed in the evaluation of changes in different regions of Turkey. Temperature anomalies of the region containing the Havran basin show that there is a significant increase in temperature for SSP2-4.5 and SSP5-8.5 for all future periods. Additionally in the same region, precipitation anomalies indicate a significant decrease in the medium and long terms whereas there is no significant change in precipitation in the short term. (Bagcaci et al.,2020)

The Impact of Climate Change on Water Resources Project was concluded in July by the Ministry of Agriculture and Forestry aims to determine the impact of climate change on surface waters and groundwater in Turkey on the basis of water basins and to determine adaptation activities. A regional climate model was run with the outputs of three global models (HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1) selected from the CMIP5 archive, which forms the basis of the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), covering 25 river basins in Turkey, including Kuzey Ege River basin that contains Havran basin. Within the scope of the project RCP4.5 and RCP8.5 emission scenarios were employed for 2015-2100 projection period. It was found that a significant decrease in total precipitation and a significant increase in temperature are expected in a large part of the Kuzey Ege River basin in both scenarios of all models. It was found that the changes in precipitation will be more pronounced after 2050 and the decrease will be up to 100 mm until the end of the century. Temperature change will be up to 3^{o}C with RCP4.5 scenario and 5.2 ^{o}C with RCP8.5 scenario and increasing temperatures will be more pronounced after 2050-2060 period. Although there was no significant change in the water potential of the basin, there is a potential of a water deficit in the basin after 2050. HadGEM2-ES model points to a water deficit problem in the basin in some periods according to the results of RCP8.5 scenario that predicts only 78% of the water demand within the basin can be met. (Ministry of Agriculture and Forestry, GDWM, 2016)

1.4 Description of Thesis

In the first chapter of this thesis, brief information on climate change, its impacts on water resources and previous studies setting basis for this study are given. The second chapter introduces the study area, data and methods used for the utilization of the data. The chapter 3 presents the results obtained from climate models and hydrological model. Also, changes in temperature, precipitation and discharge within all subbasins in study area are presented. Lastly, the overall results are discussed in chapter 4 and final conclusions are presented in chapter 5.

CHAPTER 2

STUDY AREA, DATA AND METHODS

2.1 Study Area

Havran subbasin is in the middle part of the Kuzey Ege River Basin (Figure 2.1), which is located in the Aegean region in the west of Turkey. The subbasin has a drainage area of 523.24 km^2. The altitude of the basin ranges between 0-1290 m. Havran stream flows in the east-west direction.

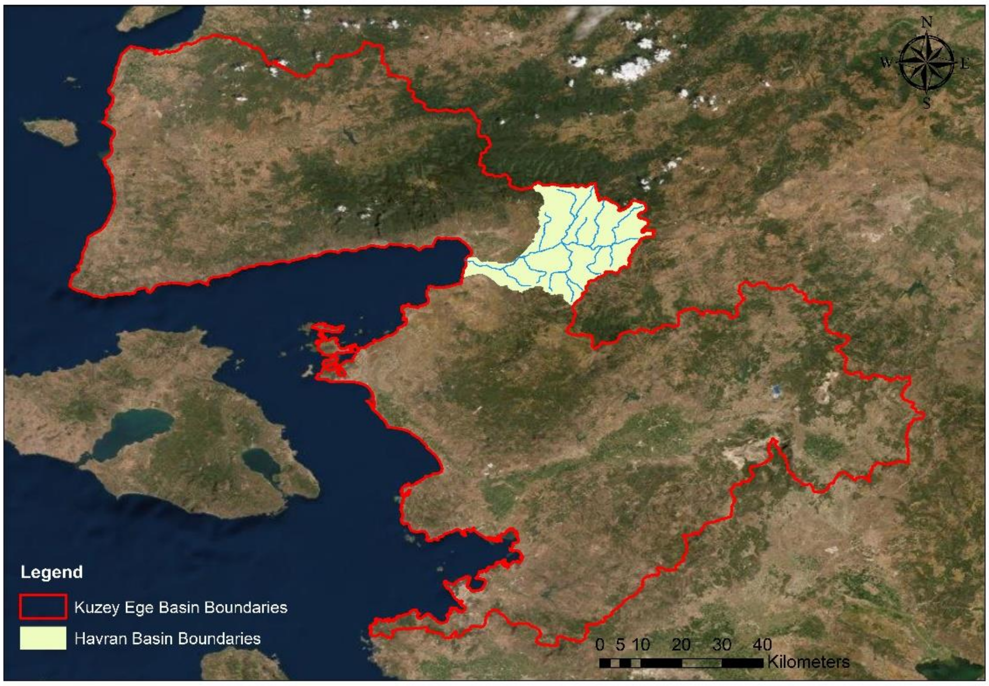


Figure 2.1 Havran Basin within Kuzey Ege River Basin

Havran and Burhaniye district centers are located in the subbasin. Livelihoods in the area are based on cattle, sheep and poultry breeding and agriculture.

As it can be seen from Figure 2.2, according to CORINE Land Cover 2012 Data, more than 68 % of the subbasin area is composed of forests, olive groves and agricultural lands. Table 2.1 shows the percent distribution of the land cover types within the Havran subbasin.

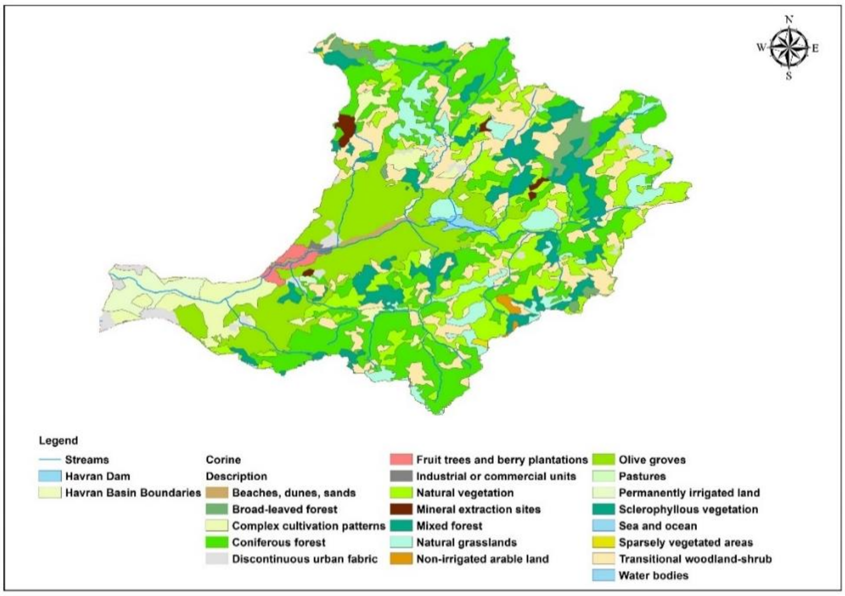


Figure 2.2 Land Cover Map of the Study Area

Table 2.1 Land Cover Types of the Study Area

Code	Description	Area (ha)	Ratio (%)
312	Coniferous forest	12086	23.1
223	Olive groves	8352	16
243	Land principally occupied by agriculture, with significant areas of natural vegetation	7811	14.9
324	Transitional woodland-shrub	7794	14.9
313	Mixed forest	4294	8.2
321	Natural grasslands	3542	6.8
242	Complex cultivation patterns	2964	5.7
212	Permanently irrigated land	1171	2.2
311	Broad-leaved forest	1034	2
112	Discontinuous urban fabric	902	1.7
323	Sclerophyllous vegetation	668	1.3
222	Fruit trees and berry plantations	432	0.8
	Other	1249	2.501

2.2 Data

2.2.1 Observation Data

Two different observational datasets were employed in this study. The first one was obtained from the General Directorate of Meteorology (GDM) and the second one is ERA5-Land data for both total precipitation and average temperature. Both are explained in the following sections.

Daily observation data of precipitation and average temperature for the period of 1975 – 2019 for two stations have been acquired from GDM. Station information on daily basis is shown in the Figure 2.3.

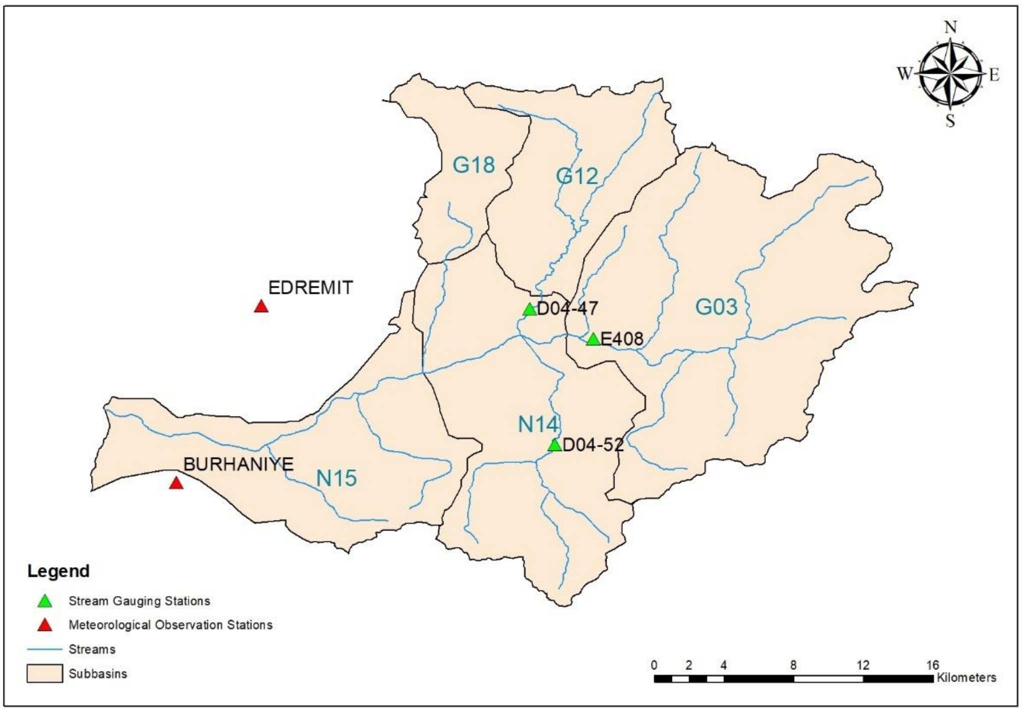


Figure 2.3 Location of Observation Stations

Table 2.2 Information on Meteorological Observation Stations

Station Name	Station No	Latitude	Longitude	Altitude	Period Available
Burhaniye	17722	39.4983	26.9755	20	1975-2020
Edremit	17145	39.5895	27.0192	21	1975-2020

Table 2.3 Information on Stream Gauging Stations

Station Name	Latitude	Longitude	Period Available
E408	39.57	27.19	1974-2014
D04-47	39.59	27.16	1974-2014
D04-52	39.52	27.17	1974-2014

2.2.2 ERA5-Land Data

The ERA5-Land dataset is a reanalysis dataset providing information on the land variables which is considered to be an improved version of ERA5 in terms of resolution. The obtained dataset is a combination of models and observations across the globe. ERA5-Land data covers several decades therefore the climate in the past can be described. The data is in gridded type with horizontal resolution of 0.1^o x 0.1^o. In this study, ERA5-Land variables Total Precipitation and 2 m Temperature are obtained in hourly temporal resolution for the historical period (1975-2014). The ERA5 Land precipitation and temperature data are used for bias correction of the GCM data. There are 12 ERA5-Land grids within the study area which are shown in the Figure 2.4.

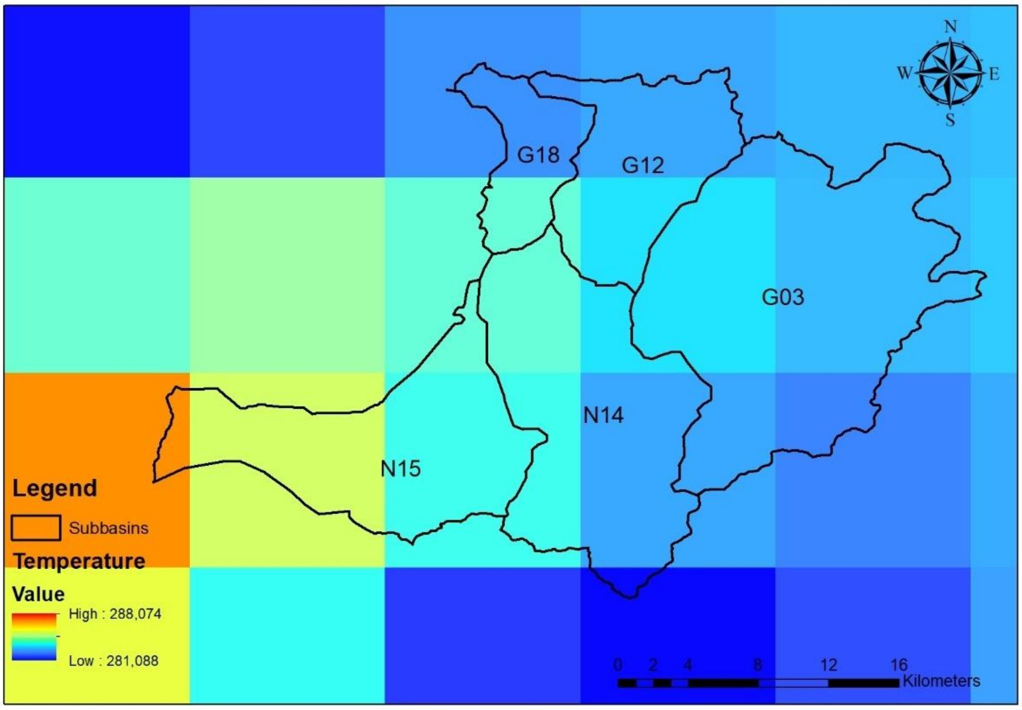


Figure 2.4 ERA5-Land Grids within the Study Area

2.2.3 Model Data

CMIP6 data for daily temperature and precipitation is obtained from the Earth System Grid Federation (ESGF) CMIP6 database. The global attributes “Source ID”, “Experiment ID”, “Variant Label”, “Frequency”, and “Variable” were filtered as described in Table 2.4, via CMIP6 database and corresponding models were downloaded.

Table 2.4 Criteria used for model data selection

Source ID	Identifies the name of the model
Experiment ID	Historical, SSP2-4.5 and SSP5-8.5 were obtained for each model, if available
Variant Label	Corresponds to the indices representing configurations of r(realisation), i (initialization method), p(physics) and f(forcing). In order to provide consistency all models were obtained in r1i1p1 configuration as possible.
Frequency	Daily data were obtained for each model. If not available in daily scale, corresponding scenario is not used.
Variable	“pr” for precipitation and “tas” for temperature models is selected.

The 10 best performing GCMs for precipitation and 13 best performing GCMs for temperature in Turkey were selected. (Bagcaci et al., 2020). Information on the GCMs employed for temperature and precipitation is given in Table 2.5.

For each model and parameter Historical data (1975-2014), SSP2-4.5 (2015-2100) and SSP5-8.5 (2015-2100) scenario data were obtained. SSP2-4.5 scenario for HadGEM3 GC31 MM did not exist during this study and SSP2-4.5 scenario daily data for CNRM CM6 1 HR model was not available therefore only SSP5-8.5 scenario was considered for these models. Information on the GCMs is given in Table 2.5. Data availability for the historical period, SSP2-4.5 and SSP5-8.5 scenarios are given in the Table 2.5.

For each parameter and each GCM, model data were extracted from the location of observation stations and ERA5-Land grid centers using ncdf4 package in R software.

Table 2.5 List of CMIP6 GCMs for Total Precipitation and Near Surface Temperature

Model Name	**Resolution**	**Modeling Institution**	**Historical**	**SSP2-4.5**	**SSP5-8.5**
HadGEM3-GC31-MM	0.5°× 0.8°	Met Office Hadley Centre (UK)	pr, tas	-	pr, tas
GFDL-ESM4	1°× 1.25°	NOAA Geophysical Fluid Dynamics Laboratory (USA)	pr	pr	pr
ACCESS-CM2	1.25°× .875°	Commonwealth Scientific and Industrial Research Organization (Australia)	pr	pr	pr
EC-Earth3	0.7°×0.7°	EC_Earth Consortium (Europe)	pr, tas	pr	pr
CNRM-CM6–1-HR	0.5°×0.5	Centre National de Recherches Météorologiques–Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (France)	pr	-	pr
MRI-ESM2–0	1.2°×1.125°	Meteorological Research Institute (Japan)	pr, tas	pr	pr
EC-Earth3-Veg	0.7°×0.7°	EC_Earth Consortium (Europe)	pr, tas	pr	pr
HadGEM3-GC31-LL	1.25°×1.875°	Met Office Hadley Centre (UK)	pr, tas	pr, tas	pr, tas
MIROC6	1.4°×1.4°	Japan Agency for Marine–Earth Science and Technology, Atmosphere and Ocean Research Institute, The University of Tokyo, National Institute for Environmental Studies, and RIKEN Center for Computational Science (Japan)	pr	pr	pr
UKESM1–0-LL	1.25°×1.875°	Met Office Hadley Centre (UK)	pr	pr	pr
MPI-ESM1–2-HR	0.9375°×0.9375°	Max Planck Institute for Meteorology (Germany)	tas	tas	tas
CNRM-ESM2–1	1.4°×1.4°	Centre National de Recherches Météorologiques–Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (France)	tas	tas	tas
NorESM2-MM	0.9375°×1.25°	Norwegian Climate Centre (Norway)	tas	tas	tas
CESM2	1.25 x 0.94	Climate and Global Dynamics Laboratory, National Center for Atmospheric Research (USA)	tas	tas	tas
CNRM-CM6–1	1.4°×1.4°	Centre National de Recherches Météorologiques–Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (France)	tas	tas	tas
CESM2-WACCM	1.25 x 0.94	Climate and Global Dynamics Laboratory, National Center for Atmospheric Research (USA)	tas	tas	tas
BCC-CSM2-MR	1.125°×1.125°	Beijing Climate Center China Meteorological Administration (China)	tas	tas	tas
CanESM5	2.8°×2.8°	Canadian Centre for Climate Modelling and Analysis (Canada)	tas	tas	tas

2.3 Methods

The methodology followed in this study is presented in the flowchart given in Figure 2.5. Firstly, three different bias correction methods were applied to raw GCM data using data taken from both observational stations and ERA5 data. Then their performance is evaluated by several performance metrics. The resulting temperature values are employed in PET calculation and together with precipitation data, they are used as GR2M model inputs. Change in precipitation, temperature and discharge in each subbasin are evaluated in the historical (1975-2014), near future (2015-2044), mid future (2045-2074) and far future (2075-2100) periods.

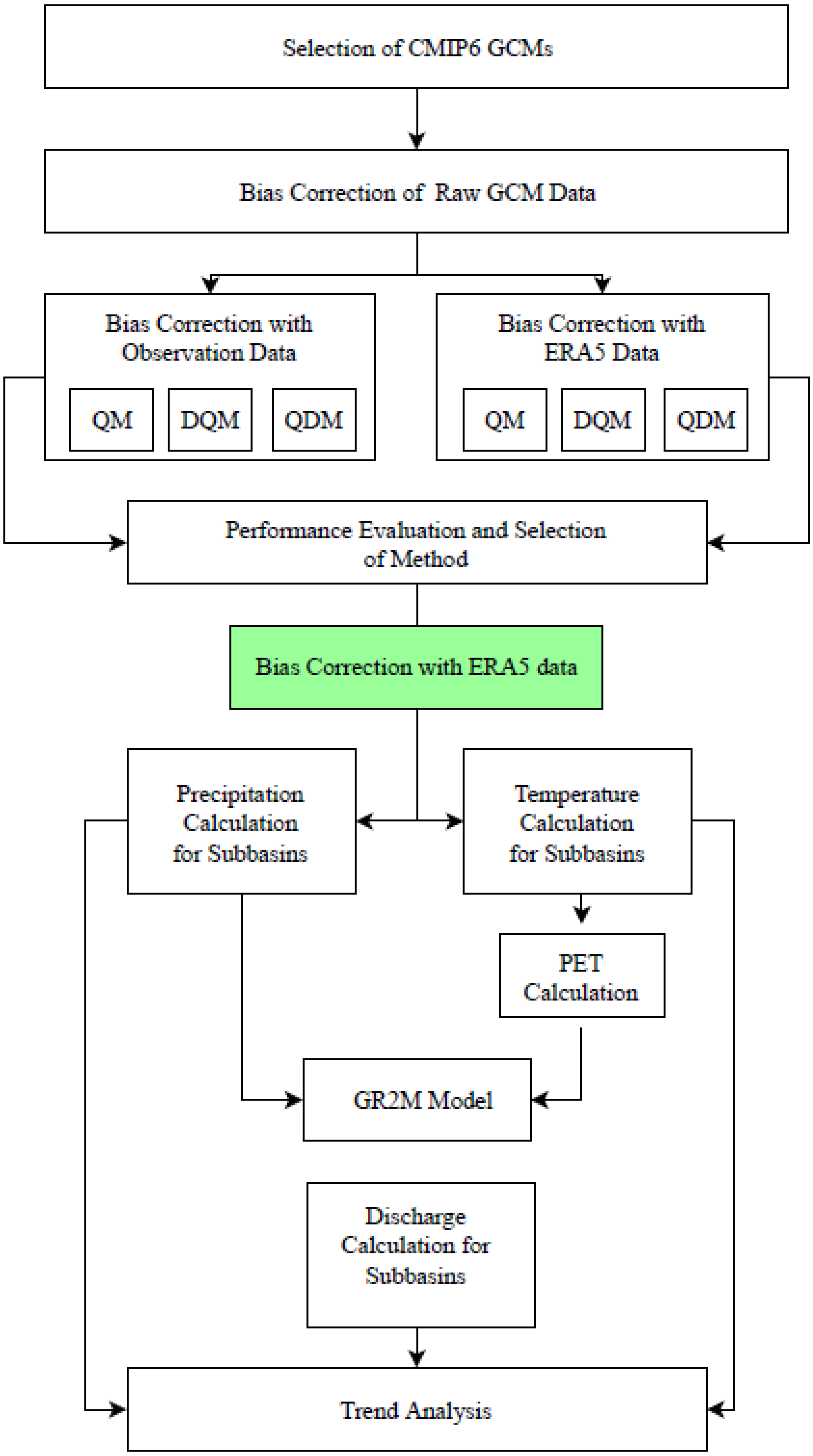


Figure 2.5 Methodology Flow Chart

2.3.1 Bias Correction

The output of GCMs needs to be preprocessed before use and gridded downscaling methods have been developed to minimize and correct the systematic biases. (Cannon et al.,2015)

Quantile Mapping (QM) method is employed to equate cumulative distribution functions of observed data and model data for the historical period. While doing so, the following transfer function is used.

$$\hat{x}_{m,p}\,(t) = \; F_{o,h}^{-1}(F_{m,h}(\; x_{m,p}(t)\;))$$

Where the subscripts, o, m, h and p are abbreviations for observed data, modeled data, historical period and projected period. $\hat{x}_{m,p}$ is modeled data for the projected period. $F_{o,h}$ and $F_{m,h}$ denotes cumulative distribution functions of observed and modeled data in historical period. In this method, only the historical period is defined. Therefore, for future data extrapolation is required. Removing the trend before quantile mapping then adding the trend is one way to avoid extrapolation. This method leads to Detrended Quantile Mapping (DQM) for which the equation is given below.

$$\hat{x}_{m,p}\,(t) = F_{o,h}^{-1}\left(\;F_{m,h}\;\left(\frac{\bar{x}_{m,h}\;x_{m,p}(t)}{\bar{x}_{m,p}(t)}\right)\right)\frac{\bar{x}_{m,p}(t)}{\bar{x}_{m,h}}$$

Here $\bar{x}_{m,h}$ and $\bar{x}_{m,p}(t)$ are representing historical period mean modeled data and mean modeled projected data at time *t*. (Cannon et al., 2015)

Quantile Delta Mapping (QDM) removes biases while preserving relative changes in quantiles. QDM procedure can be explained in two steps as calculating the relative changes in the quantiles of historical and future periods then obtaining bias corrected future data then multiplying relative changes by the historical bias corrected data. The QDM equations are initiated with the CDF of the projected model series $x_{m,p}$, where $\tau_{m,p}$ is the non-exceedance probability at time *t* as given below.

$$\tau_{m,p}(t) = F_{m,p}^{(t)}\left[x_{m,p}(t)\right],\ \ \tau_{m,p}(t)\ \in \{0,1\},$$

The relative changes between the historical period quantiles at time t is denoted as follows:

$$\Delta_m(t) = \frac{F_{m,p}^{(t)-1}[\tau_{m,p}(t)]}{F_{m,h}^{-1}\ [\tau_{m,p}(t)]} = \frac{x_{m,p}(t)}{F_{m,h}^{-1}\ [\tau_{m,p}(t)]}$$

Then, the modeled $\tau_{m,p}$ quantile at t is bias corrected using the inverse CDF obtained from observed values $x_{o,h}$ over the historical period as given below.

$$\hat{x}_{o:m,h,:p}(t) = F_{o,h}^{-1}\left[\tau_{m,p}(t)\right]$$

As the final step, the relative change $\Delta_m(t)$ is applied to the bias corrected future projections by multiplication at time t to the historical bias corrected values as given in the equation below.

$$x_{m,p}(t) = \hat{x}_{o:m,h,:p}(t)\Delta_m(t)$$

As the method is explained as detrending by quantile, $x_{o:m,h.p}$ takes the statistical characteristics of the historical period values therefore the bias between the modeled and observed quantiles are corrected. In order to introduce climate change signal bias corrected series are multiplied with Δ_m therefore the relative changes in the modeled quantiles are preserved. (Cannon et al., 2015)

In this study, all three mentioned quantile mapping-based bias correction methods are used for preprocessing of GCM data. For all GCM datasets Quantile Mapping (QM), Quantile Delta Mapping (QDM) and Detrended Quantile Mapping (DQM) are applied for the historical period (1975-2014), and future period (2015-2100) for both SSP2-4.5 and SSP5-8.5 scenarios for each observation data set within the Havran basin. Bias correction is applied for all datasets first with calibration (1975-2004) and validation (2005-2014) periods for all models. After that, the whole historical period (1975-2014) observation data is employed in bias correction of the raw GCM data for further calculations.

2.3.2 Model Performance Assessment

To evaluate the performance of different bias correction methods, root mean square error (RMSE), percent bias (PBIAS), ratio of standard deviations (rSD), Pearson's correlation coefficient (r), Kling Gupta Efficiency index (KGE) and Nash-Sutcliffe Efficiency (NSE) are employed.

Root Mean Square Error (RMSE)

The RMSE values are calculated using the following formula where z_t^{sim} is the simulated value and z_t^{obs} is the corresponding observed value.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(z_t^{sim} - z_t^{obs})^2}$$

Percent Bias (PBIAS)

Percent bias (PBIAS) shows the average tendency of model data to be larger or smaller than the observed data. The optimal value of PBIAS is 0, with low-magnitude values indicating accurate model simulation. Positive values indicate overestimation, whereas negative values indicate model underestimation bias. (Yapo & Hoshin Vijai, 1996) PBIAS is calculated as follows.

$$PBIAS = 100\,\frac{\sum_{i=1}^{N}(S_i - O_i)}{\sum_{i=1}^{N} Oi}$$

Ratio of Standard Deviations (rSD)

$$rSD = \frac{sd_{(sim)}}{sd_{(obs)}}$$

$$Standard\ Deviation\ (sd)\ = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where:

$x_i = Value\ of\ the\ i^{th}\ point\ in\ the\ data\ set$

$\bar{x} = The\ mean\ value\ of\ the\ data\ set$

$n = The\ number\ of\ data\ points\ in\ the\ data\ set$

Pearson's Correlation Coefficient (r);

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

The Pearson's correlation coefficient is a descriptive statistic, meaning that it summarizes the characteristics of a dataset. Specifically, it describes the strength and direction of the linear relationship between two quantitative variables. It helps better understand whether there is a significant relationship between two variables. r is in the range of -1 and 1.

Kling Gupta Efficiency (KGE);

$$KGE = 1 - ED$$

$$ED = \sqrt{(r-1)^2 + (\alpha-1)^2 + (\beta-1)^2}$$

$$\beta = \frac{\mu_s}{\mu_0}$$

$$\alpha = \frac{\sigma_s}{\sigma_0}$$

where ED is the Euclidian distance from the ideal point, r is the linear correlation coefficient, α is a measure of relative variability in the simulated and observed values, β is the ratio between the mean simulated and mean observed values, i.e., β represents the bias. KGE = 1 indicates perfect agreement between simulations and observations. KGE < 0 indicates that the mean of observations provides better estimates than simulations KGE range from - ∞ to 1. Essentially, the closer to 1, the more accurate the model is. (Gupta et al., 2009)

Nash-Sutcliffe Efficiency

Nash-Sutcliffe efficiency is calculated by taking one minus absolute square differences between predicted (O_i) and observed (P_i) values then normalized with the variance of observed values ($\bar{O}$) in the calibration period. The range of NSE is between 1 and -∞, 1 representing the perfect fit. The calculation is performed with the equation presented below. (Krause et al., 2005)

$$NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2}$$

2.3.3 Trend Analysis

The trend in the precipitation, temperature and discharge are calculated for seasonal and annual basis using the Mann Kendall test (Mann, 1945; Kendall, 1975) and Sen's slope estimator (Sen, 1968).

Mann Kendall test statistics are calculated using the following formula.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i)$$

n representing the number of data points while x_i and x_j are the data values from the time series being j>i. $sgn(x_j - x_i)$ is calculated as:

$$sgn(x_j - x_i) = \begin{cases} 1, if\ (x_j - x_i) > 0 \\ 0, if\ (x_j - x_i) = 0 \\ 1, if\ (x_j - x_i) < 0 \end{cases}$$

The variance is calculated as follows

$$Var\ (S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18}$$

Where n is the number of data points, m is the number of tied groups and t_i is the number of tied values of extend i. If the sample size n>10, the standard test statistics Z is computed with the following formula.

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, if\ S > 0 \\ 0, \quad if\ S = 0 \\ \frac{S-1}{\sqrt{Var(S)}}, i \end{cases}$$

The calculated Z values represent an increasing trend when Z is positive and decreasing trend when Z is negative. The tests are performed under a specific α significance level. If $|Z_s|>Z_{1-\alpha/2}$, the null hypothesis is rejected and there is a significant trend at the time series (Gocic & Trajkovic, 2013)

The non-parametric procedure that is used to estimate slope of the trend in a sample of N pairs of data is Sen's slope estimator for which the formula is given below.

$$Q_i = \frac{x_i - x_k}{j-k} \quad for\ i = 1, \dots, N$$

In which x_i *and* x_k are the data at times j and k given j>k. Corresponding Q values are calculated for odd number of data and even number of data with the following formulas respectively. Sign of the Q_{med} shows the direction of trend, while its value represents the change in unit time.

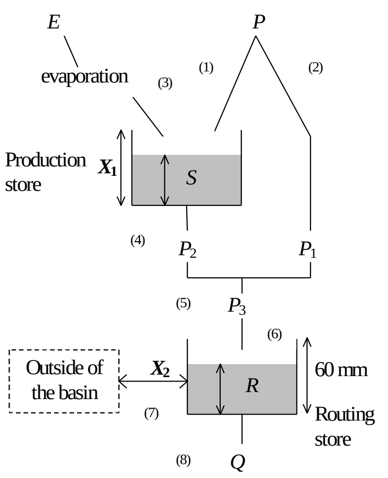
$$Q_{med} = Q_{(N+1)/2}$$

$$Q_{med} = \frac{1}{2}[Q_{\frac{N}{2}} + Q_{(N+2)/2}$$

2.3.4 Hydrological Model

GR2M is a semi-empirical model which is commonly used for hydrological modeling as a result of its high consistency. (Huard & Mailhot, 2008)

GR2M model which was developed by Maklouf and Mitchel (1994) and later advanced by Mouelhi, Mitchel, Perrin and Andreassian is used in hydrological calculations. The model uses monthly precipitation and potential evapotranspiration values in calculation of monthly discharge. The model equations and scheme are given in Figure 2.6.



(1) $S_1 = \dfrac{S + X_1\varphi}{1 + \varphi \dfrac{S}{X_1}}$ with $\varphi = \tanh\left(\dfrac{P}{X_1}\right)$

(2) $P_1 = P + S - S_1$

(3) $S_2 = \dfrac{S_1(1-\psi)}{1 + \psi\left(1 - \dfrac{S_1}{X_1}\right)}$ with $\psi = \tanh\left(\dfrac{E}{X_1}\right)$

(4) $S = \dfrac{S_2}{\left[1 + \left(\dfrac{S_2}{X_1}\right)^3\right]^{1/3}}$ $P_2 = S_2 - S$

(5) $P_3 = P_1 + P_2$

(6) $R_1 = R + P_3$

(7) $R_2 = X_5 . R_1$

(8) $Q = \dfrac{R_2^2}{R_2 + 60}$ $R = R_2 - Q$

Figure 2.6 GR2M Model scheme and model equations (Zubieta et al., 2021)

The model is depending on two reservoirs (S_1 and S_2) and two calibration parameters (X_1 and X_2). X_1 represents the maximum capacity of the soil moisture reservoir at the production store which is a positive value denoted with S, typically changing in the range of 22-800 mm. Routing store capacity is set as 60 mm and its actual value is represented by R. X_2 is the exchange coefficient theoretically changing in the range of 0-1.3 and is dimensionless. If X_2 parameter is smaller than 1 it means that there is water loss from the catchment. (Rau, et al., 2019)

P (mm/month) and E (mm/month) are representing monthly precipitation and monthly evapotranspiration respectively and required inputs for the model.

In order to determine the hydrological model parameters, the model should be calibrated with observed discharge. Therefore, the model parameters are determined by calibrating to produce the closest output to observed discharge under precipitation and potential evapotranspiration inputs. Model calibration is performed using naturalized observed discharge values. Therefore, the impact of Havran Dam and all other engineering structures are not considered. GR2M model runs are performed for each subbasin with observed discharge to obtain specific model parameters. Calibration and verification periods for modeled subbasins are given in Table 2.6 along with calculated model parameters. It should be noted that the subbasins (G18 and N15) are not calibrated as there was no observation. Instead, model parameters for G18 and N15 basins are taken from G12 and N14 subbasins respectively.

Table 2.6 GR2M model parameters for each subbasin

Subbasin	**X_1**	**X_2**	**DSI Observation Station**	**Calibration Period**	**Verification Period**
G03	354.05	0.96	E408	01.01.1982 01.05.1990	01.05.1990 01.09.2014
G12	511.95	1.07	D04-47	01.01.1982 01.05.1990	01.05.1990 01.09.14
G18	511.95	1.07	-	-	-
N14	356.30	0.99	D04-52	01.01.1982 01.05.1990	01.05.1990 01.09.2014
N15	356.30	0.99	-	-	-

Table 2.7 GR2M model calibration metrics

Performance Metric	**G03**		**G12**		**N14**	
	Calibration	Validation	Calibration	Validation	Calibration	Validation
Nash	0,681	0,70	0,85	0,79	0,85	0,81
PBIAS	-7,55	-4,82	-2,64	2,29	2,27	4,91
R^2	0,709	0,704	0,894	0,8	0,89	8,22

For each subbasin 9 model runs are performed using different combinations of GCM data. The model combinations are presented in Table 2.8. It should be noted that M7 and M9 scenarios are only employed in the historical period and not used for further evaluation because HadGEM3-GC31-MM model future simulations for SSP2-4.5 is lacking. Also, CNRM-CM6-1-HR model output for SSP2-4.5 was not available in daily frequency. Since the bias correction methods are applied to daily data, it was not included in monthly basis in order to follow same methodology for all models. Consequently, those two models are included in the historical period for M7 and M9 to visualize their difference from M6 and M8 model runs.

Table 2.8 Model runs and employed precipitation and temperature data

No	Precipitation Models Employed	Temperature Models Employed
M1	EC Earth3	EC Earth3
M2	EC Earth3 Veg	EC Earth3 Veg
M3	HadGEM3 GC31 LL	HadGEM3 GC31 LL
M4	HadGEM3 GC31 MM	HadGEM3 GC31 MM
M5	MRI ESM2 0	MRI ESM2 0
M6	EC Earth3, EC Earth3 Veg, HadGEM3 GC31 LL, MRI ESM2 0	EC Earth3, EC Earth3 Veg, HadGEM3 GC31 LL, MRI ESM2 0
M7	EC Earth3, EC Earth3 Veg, HadGEM3 GC31 LL, HadGEM3 GC31 MM, MRI ESM2 0	EC Earth3, EC Earth3 Veg, HadGEM3 GC31 LL, HadGEM3 GC31 MM, MRI ESM2 0
M8	ACCESS CM2, GFDL ESM4, CNRM CM6 1 HR, MIROC6, UKESM1 0 LL, EC Earth3, EC Earth3 Veg, HadGEM3 GC31 LL, MRI ESM2 0	MPI-ESM1–2-HR, CNRM-ESM2–1, NorESM2-MM, MRI-ESM2–0, EC-Earth3-Veg, CESM2, CNRM-CM6–1, CESM2-WACCM, BCC-CSM2-MR, CanESM5, EC-Earth3, HadGEM3-GC31-LL
M9	ACCESS CM2, GFDL ESM4, CNRM CM6 1 HR, MIROC6, UKESM1 0 LL, EC Earth3, EC Earth3 Veg, HadGEM3 GC31 LL, HadGEM3 GC31 MM, MRI ESM2 0	MPI-ESM1–2-HR, CNRM-ESM2–1, NorESM2-MM, MRI-ESM2–0, EC-Earth3-Veg, CESM2, HadGEM3-GC31-MM, CNRM-CM6–1, CESM2-WACCM, BCC-CSM2-MR, CanESM5, EC-Earth3, HadGEM3-GC31-LL

In addition, ERA5-Land precipitation and temperature data are employed in GR2M model for historical period and presented as ERA5 observational discharge.

ERA5-Land data and bias correction outputs are spatially averaged before using them as input for GR2M model. Figure 2.4 shows each model subbasins and corresponding ERA5 Land grids.

2.3.4.1 PET Calculation

Potential evapotranspiration (PET) is the water loss as a result of transpiration of plants and water evaporation from the earth's surface. PET is influenced by temperature, humidity, sunlight and wind. Evapotranspiration is an important parameter in order to estimate water balance in a basin. PET values are calculated using the model based on the modified Jensen–Haise (1963) and McGuinness (1972) methods. Monthly potential evapotranspiration can be successfully calculated with monthly mean temperature and extra-terrestrial radiation values depending on latitude and Julian day. (Oudin, et al., 2005)

Temperature GCM outputs employed in PET calculation are given in Table 2.8.

CHAPTER 3

RESULTS

In this chapter evaluation of bias correction results is presented. Bias correction of the GCM data is performed using two different observational datasets and three different methods overall. Then performance of three different bias correction methods is evaluated before employing them within GR2M model.

After selection of bias correction method, evaluation is made based on spatially averaged precipitation and temperature variables and calculated discharge amounts for each subbasin. All subbasins are inspected within the historical period (1975-2014), near future (2015-2044), mid future (2045-2074) and far future (2075-2100) periods for both SSP2-4.5 and SSP5-8.5 scenarios separately, then all results are subjected to trend analysis.

3.1 Evaluation of Bias Correction Methods

3.1.1 Station Observation Data

Station observation data taken from GDM is used for bias correction of each GCM outputs for both total precipitation and average temperature variables.

The annual maximum precipitations obtained from two observation stations (Burhaniye and Edremit) were accepted as they fit the GEV distribution and parameter estimations of distribution are made according to the maximum likelihood method. Thus, the precipitation values that may occur at return levels from 2 to 1000 years were estimated from Inverse Cumulative Density Function.

Figure 3.1 shows frequency curves for EC-Earth3 model and maximum annual precipitation distribution for Raw, QM, QDM and DQM methods together with

Station Observation data for both Burhaniye and Edremit stations. Also, maximum precipitation values are obtained for Burhaniye and Edremit station. At Burhaniye Station maximum precipitation values are obtained between 1984 - 2000 and at Edremit station data was obtained for 1965 - 2000. They are included in the graphs given in Figure 3.1 as “Burhaniye MGM” and “Edremit MGM” for comparison. Remaining maximum precipitation graphs are given in Appendix-A.

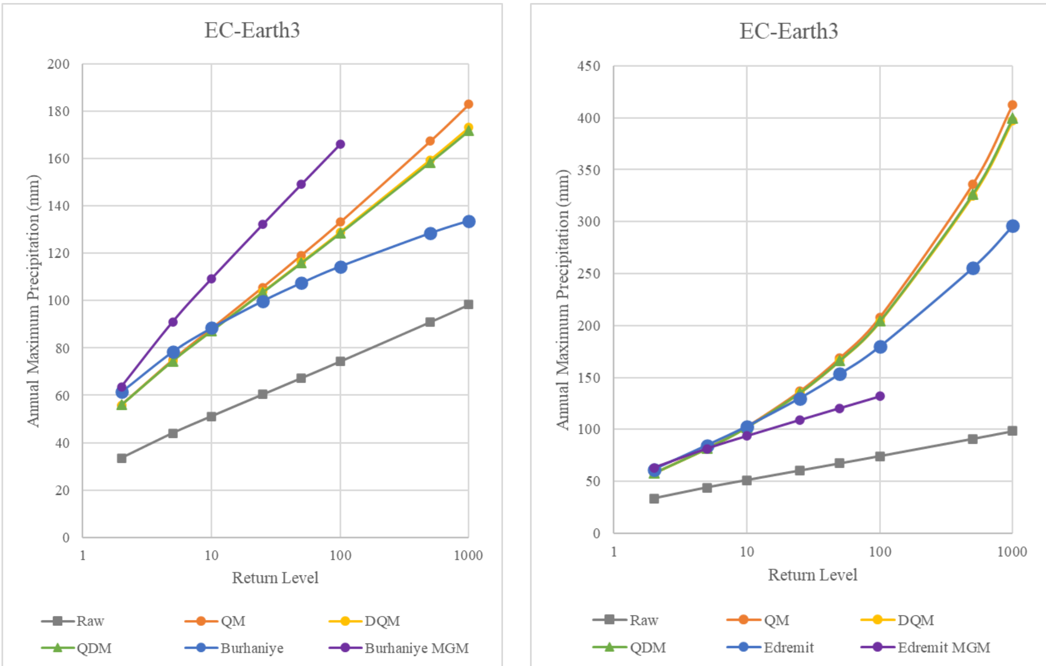


Figure 3.1 Maximum precipitation graphs for Burhaniye and Edremit stations for EC Earth3 Model

Then the simulated and observed values are compared using RMSE, PBIAS, rSD and r metrics for raw GCM output and bias corrected datasets. Mean performance metrics for precipitation and temperature are given in Table 3.1 and Table 3.2.

Table 3.1 Mean performance metrics for bias correction of precipitation (GDM Observation)

Parameters	Raw	QM	QDM	DQM
KGE	0.29	0.38	0.38	0.38
PBIAS	10.06	0.03	0	0
r	0.41	0.39	0.39	0.39
RMSE	63.97	65.65	65.70	65.71
rSD	0.88	0.99	0.99	0.99

Table 3.2 Mean performance metrics for bias correction of temperature (GDM Observation)

Parameters	Raw	QM	QDM	DQM
KGE	0.84	0.95	0.95	0.95
PBIAS	-7.9	0.027	0.02	0.02
r	0.95	0.95	0.95	0.95
RMSE	2.77	2.2	2.2	2.2
rSD	0.99	1	1	1

Bias correction methods show better performance for temperature values. Considering bias correction results of precipitation values, PBIAS values are getting closer to 0, rSD values are approaching 1 and KGE values slightly increased. However, RMSE values are increasing and correlations are decreasing where the opposite is favored. Therefore, the observational dataset is replaced with ERA5-Land data for both precipitation and temperature values.

3.1.2 ERA5-Land Data

In the scatter plots given in Figure 3.2 and Figure 3.3, ERA5-Land and station observation monthly data are compared. It was seen that there is a high linear relationship between observed and ERA5 values for both precipitation and temperature variables. Data distribution is closer to observed values with the temperature data.

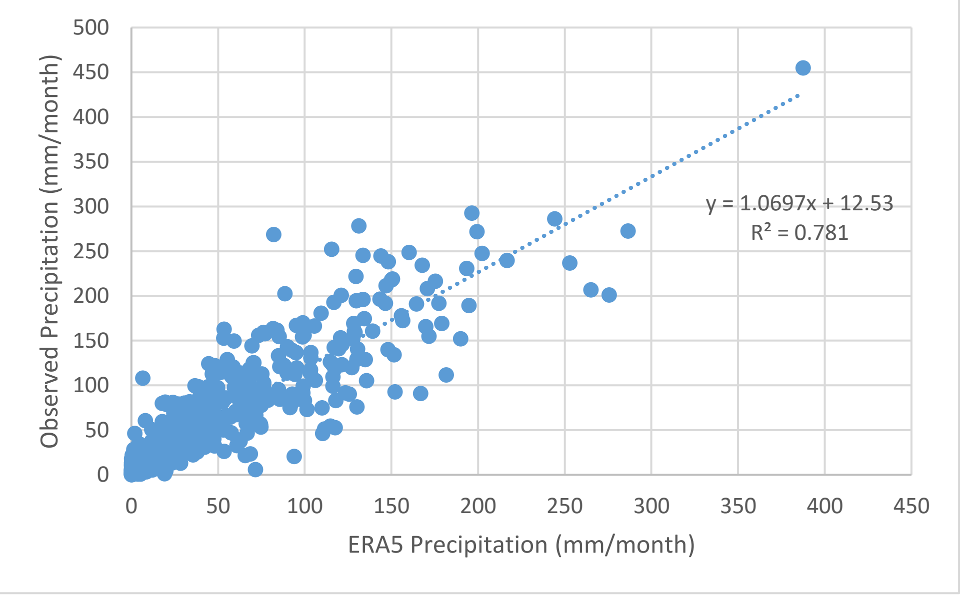


Figure 3.2 Comparison of ERA5-Land and Observed Monthly Total Precipitation

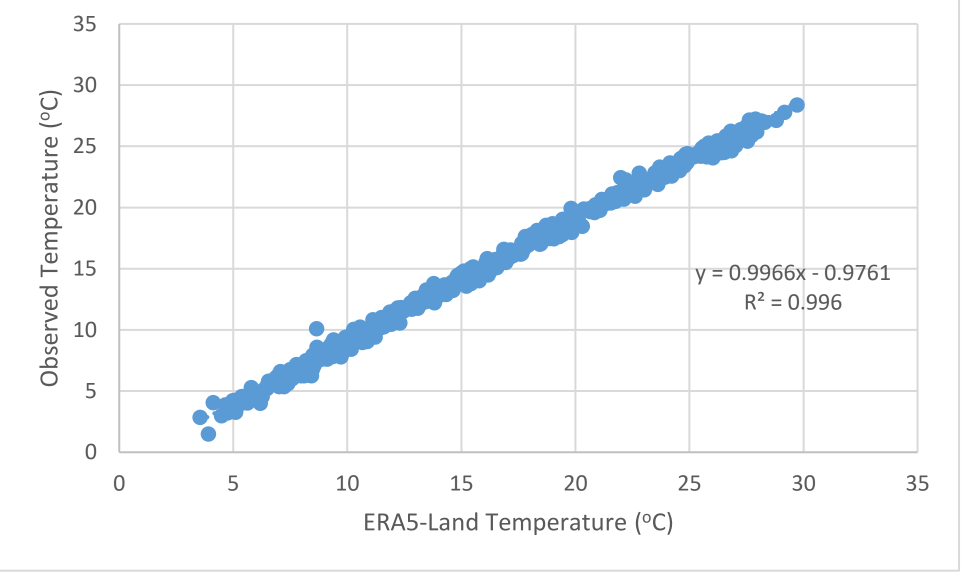


Figure 3.3 Comparison of ERA5-Land and Observed Monthly Mean Temperature

Data obtained from raw GCM data for each model are bias corrected in each ERA5 grid. There are 12 ERA5-Land data grids within the study area as it was shown in Figure 2.4 .

As mentioned in the Chapter 2.3.1, bias correction is performed with calibration (1975-2004) and validation periods first. Calibration and validation metrics are given in Table 3.3 and Table 3.4 for precipitation and temperature respectively. After calibration and validation of the bias correction methods are performed, bias correction is applied using whole historical range for all raw GCMs for further calculations.

Table 3.3 Calibration and validation metrics for precipitation models

		Calibration					Validation				
Model	**Parameters**	PBIAS	rSD	d	r	KGE	PBIAS	rSD	d	r	KGE
ACCESS CM2	**Raw**	-17	0.88	0.63	0.39	0.35	-25.5	0.8	0.56	0.3	0.23
	QM	0	0.97	0.64	0.39	0.39	-9.9	0.9	0.59	0.32	0.31
	QDM	-0.2	0.97	0.64	0.39	0.39	-11	0.88	0.59	0.33	0.31
	DQM	0	0.97	0.64	0.39	0.39	-10.4	0.89	0.59	0.32	0.3
CNRM CM6 1 HR	**Raw**	76.2	1.47	0.55	0.42	-0.07	55.5	1.29	0.64	0.5	0.2
	QM	-0.1	0.94	0.64	0.41	0.41	-11.8	0.82	0.69	0.49	0.45
	QDM	-0.2	0.94	0.64	0.41	0.41	-11.2	0.82	0.7	0.5	0.45
	DQM	0	0.95	0.64	0.41	0.41	-10	0.82	0.7	0.5	0.46
EC Earth3	**Raw**	-18.4	0.85	0.69	0.49	0.44	-13.5	0.86	0.67	0.45	0.41
	QM	0	1.04	0.71	0.5	0.5	6.3	1.05	0.67	0.45	0.44
	QDM	-0.2	1.04	0.7	0.5	0.5	6.1	1.05	0.67	0.45	0.44
	DQM	0	1.04	0.71	0.5	0.5	6	1.05	0.67	0.45	0.44
EC Earth3 Veg	**Raw**	-13.4	0.89	0.67	0.45	0.43	-18.6	0.89	0.66	0.45	0.41
	QM	0	1.03	0.67	0.45	0.45	-5.4	1.04	0.67	0.46	0.45
	QDM	-0.2	1.03	0.67	0.45	0.45	-6.5	1.03	0.67	0.46	0.45
	DQM	0	1.03	0.67	0.45	0.45	-5.4	1.04	0.67	0.45	0.45
GFDL ESM4	**Raw**	-9.3	0.81	0.63	0.4	0.37	-22.4	0.69	0.61	0.41	0.29
	QM	3	1	0.63	0.39	0.39	-12.1	0.84	0.63	0.4	0.37
	QDM	2.8	1	0.63	0.39	0.39	-11	0.84	0.63	0.4	0.37
	DQM	3.1	1	0.63	0.39	0.39	-10.5	0.85	0.63	0.4	0.38
HadGEM3 GC31 LL	**Raw**	-21.2	0.96	0.63	0.4	0.36	-32.5	0.87	0.69	0.52	0.4
	QM	-0.6	1.06	0.67	0.45	0.45	-12.6	1.02	0.73	0.53	0.52
	QDM	-0.2	1.07	0.67	0.45	0.45	-14.9	1	0.73	0.54	0.51
	DQM	0	1.07	0.67	0.45	0.45	-14	1.01	0.73	0.53	0.51
HadGEM3 GC31 MM	**Raw**	-16.8	1.01	0.67	0.47	0.44	-29.3	0.86	0.65	0.45	0.36
	QM	-1.9	1.04	0.72	0.53	0.53	-14.8	0.91	0.7	0.51	0.48
	QDM	-0.2	1.08	0.71	0.52	0.52	-15.4	0.92	0.7	0.49	0.47
	DQM	0	1.08	0.71	0.52	0.51	-14.8	0.93	0.7	0.49	0.47
MIROC6	**Raw**	-21.1	0.69	0.62	0.42	0.31	-29.5	0.64	0.64	0.47	0.29
	QM	0	0.9	0.65	0.42	0.41	-10.7	0.83	0.68	0.47	0.43
	QDM	-0.2	0.89	0.65	0.42	0.41	-10.8	0.83	0.68	0.47	0.43
	DQM	0	0.89	0.65	0.42	0.41	-10.6	0.83	0.68	0.47	0.43
MRI ESM2 0	**Raw**	-12.3	0.84	0.64	0.42	0.39	-15.7	0.84	0.71	0.51	0.46
	QM	0	0.99	0.64	0.42	0.42	-3.4	1	0.72	0.51	0.51
	QDM	-0.2	0.98	0.64	0.42	0.42	-4.1	1	0.72	0.5	0.5
	DQM	0	0.98	0.64	0.42	0.42	-3.6	1	0.72	0.51	0.5
UKESM1 0 LL	**Raw**	-22.3	1.01	0.69	0.49	0.45	-19.4	1.01	0.77	0.61	0.56
	QM	-0.8	1.12	0.72	0.52	0.51	2.9	1.17	0.76	0.59	0.56
	QDM	-0.2	1.13	0.72	0.52	0.5	7	1.21	0.76	0.59	0.53
	DQM	0	1.13	0.72	0.52	0.5	5.9	1.21	0.76	0.6	0.54

Table 3.4 Calibration and validation metrics for temperature models

		Calibration					Validation				
Model	**Parameters**	PBIAS	rSD	d	r	KGE	PBIAS	rSD	d	r	KGE
BCC CSM2 MR	**Raw**	26.5	0.69	0.83	0.85	0.56	22	0.71	0.85	0.85	0.61
	QM	-0.1	1.07	0.91	0.83	0.81	-1.1	1.11	0.91	0.84	0.81
	QDM	-0.1	1.07	0.91	0.83	0.81	-3.1	1.08	0.91	0.84	0.82
	DQM	-0.1	1.07	0.91	0.83	0.81	-4	1.13	0.91	0.83	0.78
Can ESM5	**Raw**	28.7	0.95	0.92	0.96	0.71	28.7	0.93	0.91	0.96	0.7
	QM	0	1.01	0.98	0.96	0.96	2.7	0.98	0.98	0.96	0.95
	QDM	0	1.01	0.98	0.96	0.96	1.7	0.98	0.98	0.96	0.95
	DQM	0	1.01	0.98	0.96	0.96	1.7	0.98	0.98	0.96	0.95
CESM2	**Raw**	28.9	1.13	0.92	0.95	0.68	27.5	1.15	0.93	0.97	0.69
	QM	0	1.01	0.97	0.95	0.95	-0.7	1.02	0.98	0.96	0.96
	QDM	0	1.01	0.97	0.95	0.95	0.2	1.03	0.98	0.97	0.95
	DQM	0	1.01	0.97	0.95	0.95	-0.1	1.03	0.98	0.97	0.96
CESM2 WACCM	**Raw**	28.8	1.08	0.92	0.95	0.7	28.7	1.11	0.93	0.97	0.69
	QM	0	1	0.98	0.95	0.95	0.8	1.03	0.98	0.97	0.96
	QDM	0	1	0.98	0.95	0.95	1.6	1.04	0.98	0.97	0.95
	DQM	0	1	0.98	0.95	0.95	1.3	1.04	0.98	0.97	0.95
CNRM CM6 1	**Raw**	23.3	0.97	0.94	0.95	0.76	21.8	0.98	0.94	0.96	0.78
	QM	0	1	0.98	0.95	0.95	0	1.01	0.98	0.96	0.96
	QDM	0	1	0.98	0.95	0.95	-0.2	1.02	0.98	0.96	0.95
	DQM	0	1	0.98	0.95	0.95	-0.4	1.02	0.98	0.96	0.95
CNRM ESM2 1	**Raw**	29.5	1	0.91	0.95	0.7	29.5	1.01	0.92	0.96	0.7
	QM	0	1.01	0.97	0.95	0.95	1.6	1.01	0.98	0.96	0.95
	QDM	0	1.01	0.97	0.95	0.95	1.8	1.01	0.98	0.96	0.95
	DQM	0	1.01	0.97	0.95	0.95	1.4	1.01	0.98	0.96	0.96
EC Earth3	**Raw**	8.8	1.22	0.96	0.95	0.76	13.3	1.14	0.97	0.97	0.8
	QM	0	1.01	0.98	0.95	0.95	3	0.94	0.98	0.97	0.93
	QDM	0	1.01	0.98	0.95	0.95	5.1	0.94	0.98	0.97	0.91
	DQM	0	1.01	0.98	0.95	0.95	4.8	0.95	0.98	0.97	0.93
EC Earth3 Veg	**Raw**	15.5	1.17	0.96	0.95	0.77	13.6	1.18	0.96	0.96	0.77
	QM	0	1.01	0.98	0.95	0.95	-1.9	1.01	0.98	0.96	0.95
	QDM	0	1.01	0.98	0.95	0.95	-1	1.02	0.98	0.96	0.95
	DQM	0	1.01	0.98	0.95	0.95	-1.2	1.02	0.98	0.96	0.95
HadGEM3 GC31 LL	**Raw**	9.5	0.86	0.95	0.94	0.82	13.2	0.84	0.96	0.96	0.79
	QM	0	1.01	0.97	0.94	0.94	5.8	0.98	0.98	0.96	0.93
	QDM	0	1.01	0.97	0.94	0.94	4.2	0.98	0.98	0.96	0.94
	DQM	0	1.01	0.97	0.94	0.94	4.2	0.98	0.98	0.96	0.94
HadGEM3 GC31 MM	**Raw**	3.4	0.97	0.97	0.94	0.93	4	0.98	0.98	0.96	0.94
	QM	0	1	0.97	0.94	0.94	0.6	1	0.98	0.96	0.96
	QDM	0	1	0.97	0.94	0.94	0.7	1.01	0.98	0.96	0.96
	DQM	0	1	0.97	0.94	0.94	0.5	1.01	0.98	0.96	0.96
MPI ESM1 2 HR	**Raw**	25.4	1.14	0.94	0.96	0.71	22.7	1.1	0.94	0.97	0.75
	QM	0	1	0.98	0.96	0.96	-1.8	0.97	0.98	0.96	0.95
	QDM	0	1	0.98	0.96	0.96	-1.2	0.97	0.98	0.96	0.95
	DQM	0	1	0.98	0.96	0.96	-1.3	0.97	0.98	0.96	0.95
MRI ESM2 0	**Raw**	18.6	0.89	0.94	0.95	0.78	19.7	0.86	0.94	0.96	0.76
	QM	0	1	0.98	0.95	0.95	3.3	0.97	0.98	0.96	0.94
	QDM	0	1	0.98	0.95	0.95	2.3	0.97	0.98	0.96	0.94
	DQM	0	1	0.98	0.95	0.95	2.1	0.97	0.98	0.96	0.95
NorESM2 MM	**Raw**	22.2	0.91	0.94	0.95	0.76	20.7	0.92	0.94	0.96	0.77
	QM	0	1.01	0.98	0.95	0.95	0.6	1.02	0.98	0.96	0.96
	QDM	0	1.01	0.98	0.95	0.95	-0.2	1.02	0.98	0.96	0.96
	DQM	0	1.01	0.98	0.95	0.95	-0.2	1.02	0.98	0.96	0.96

Figure 3.4, Figure 3.5 and Figure 3.6 shows RMSE, correlation coefficient (r) and KGE values calculated between observed and bias corrected GCM data. Bias correction is performed within each ERA5 grid for all Raw GCM data. Mean performance metrics of each GCM are given in Appendix-A.

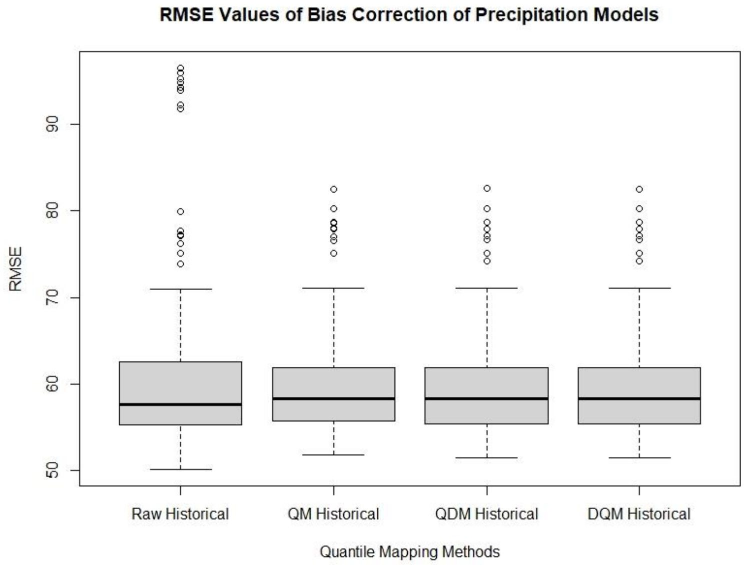


Figure 3.4 RMSE Values of Bias Corrected Precipitation Models using ERA5 Land Data

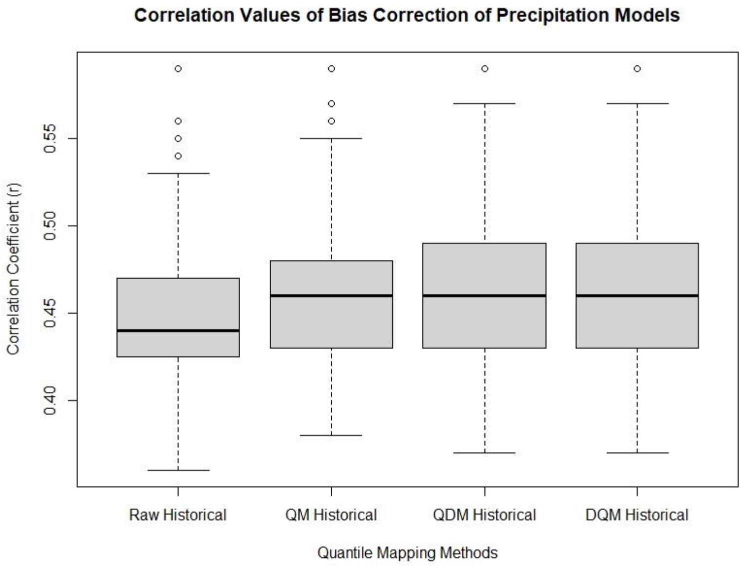


Figure 3.5 Correlation Coefficients of Bias Corrected Precipitation Models using ERA5 Land Data

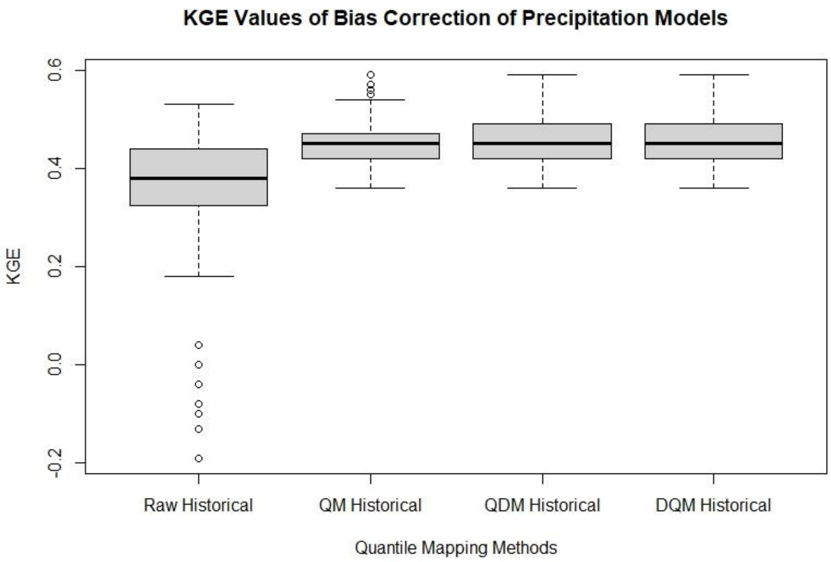


Figure 3.6 KGE Values of Bias Corrected Precipitation Models using ERA5 Land Data

RMSE values are slightly decreasing as oppose to station observation data. Correlation between the ERA5 Land precipitation and bias corrected model data increases in comparison with the raw model data. Similarly, KGE values are overall increasing with bias correction.

Figure 3.7, Figure 3.8 and Figure 3.9 shows RMSE, correlation coefficient (r) and KGE values for all bias correction that is performed within all ERA5 grids for all GCMs.

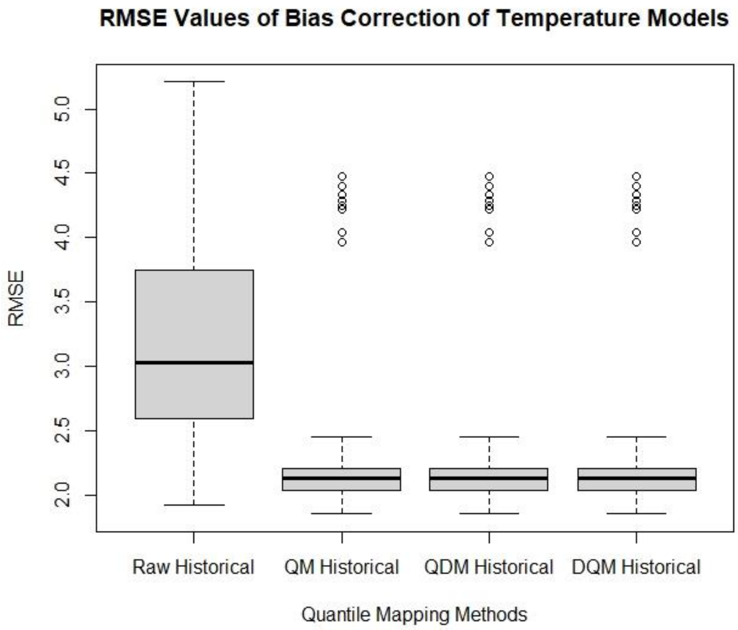


Figure 3.7 RMSE Values of Bias Corrected Temperature Models using ERA5 Land Data

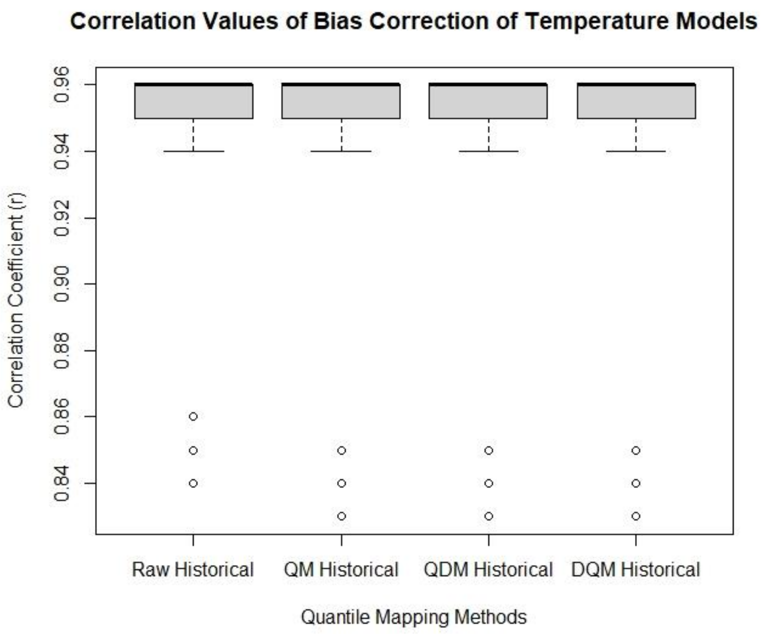


Figure 3.8 Correlation Coefficients of Bias Corrected Temperature Models using ERA5 Land Data

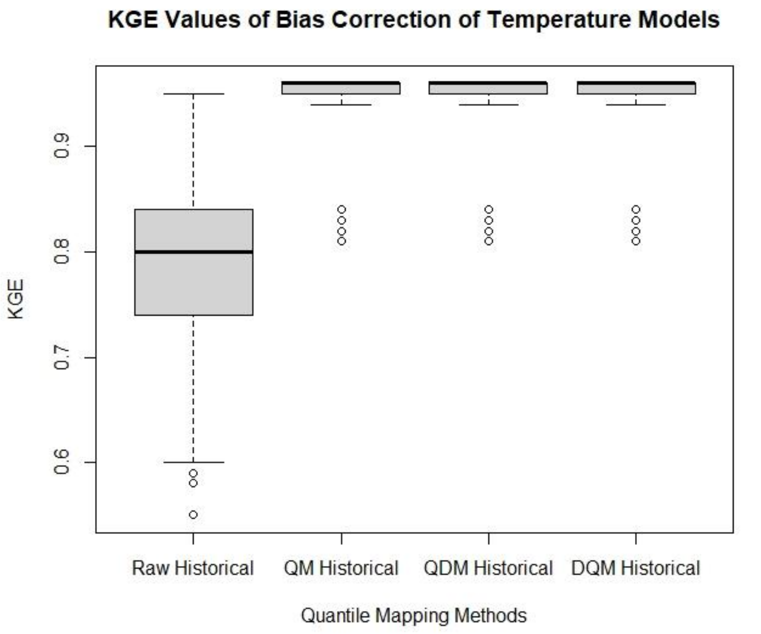


Figure 3.9 KGE Values of Bias Corrected Temperature Models using ERA5 Land Data

Raw GCM data and bias corrected data are compared with ERA5-Land Temperature data. It was seen that RMSE values become considerably low after bias correction with each method. Correlation coefficients do not show any significant change as there are already a strong linear relationship between ERA5 Land Temperature and GCM Temperature outputs. KGE values become considerably higher after bias correction.

As it can be seen from RMSE, correlation and KGE values, the difference between bias correction methods is not clear. Therefore, the performance of each quantile mapping based bias correction method is evaluated with the annual maximum precipitations for each GCM data.

The annual maximum precipitations obtained from ERA5 Land observations and bias correction results were accepted as they fit the GEV distribution and parameter estimations of distribution are made according to the maximum likelihood method. Thus, the precipitation values that may occur at return levels from 2 to 1000 years were estimated from Inverse Cumulative Density Function.

Figure 3.10 show frequency curves for EC-Earth3 and GFDL ESM4 models and maximum annual precipitation distribution for Raw, QM, QDM and DQM methods together with ERA5 Observed data. Between QDM and DQM methods, QDM is slightly closer to the observation than DQM in many of the models. Although the difference between QDM and DQM methods is not that obvious they are distinctly distinguished from QM method. Therefore, the studies carried out within the scope of this study were continued with QDM method. Remaining frequency curves are presented in Appendix-A for each GCM.

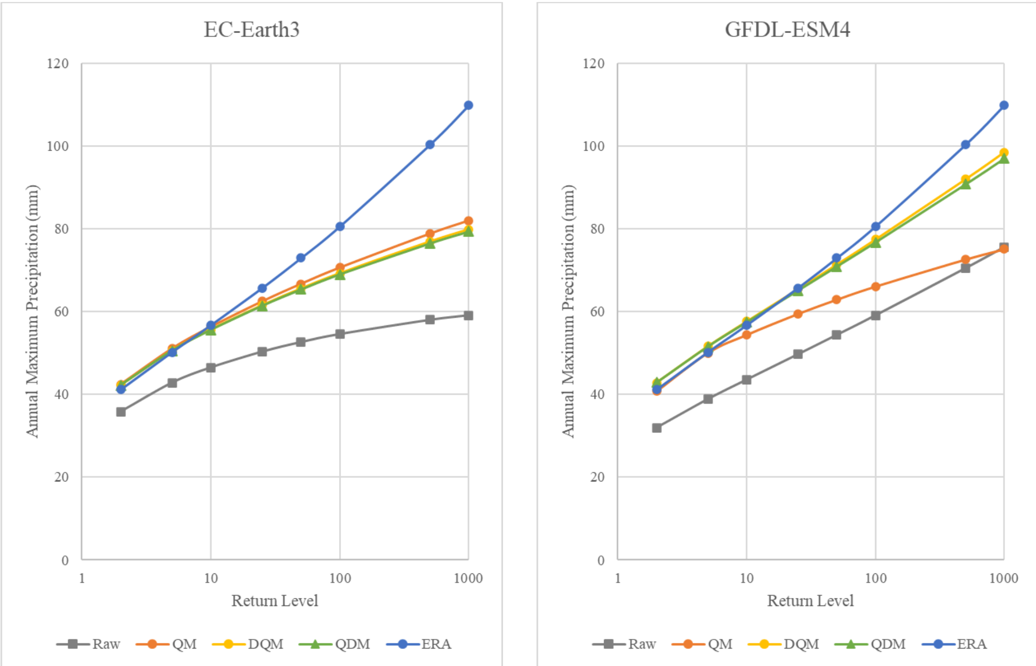


Figure 3.10 EC Earth3 and GFDL-ESM4 Models Frequency Curves

After calculation of maximum precipitations for each return level for each model, maximum precipitation values for each ERA5 grid for model ensembles for Raw GCM and bias corrected precipitation data. Through Figure 3.11 - Figure 3.15, maximum precipitations with 20 years return period for ERA5 Land Observation, Raw GCM data, QM bias corrected data, DQM bias corrected data and QDM bias corrected precipitation data are presented respectively. Maximum precipitations are calculated from the ensemble means of all precipitation models.

As it can be seen from the maximum precipitation values, DQM and QDM methods performed gave more similar results to ERA5 observations in comparison to the QM method.

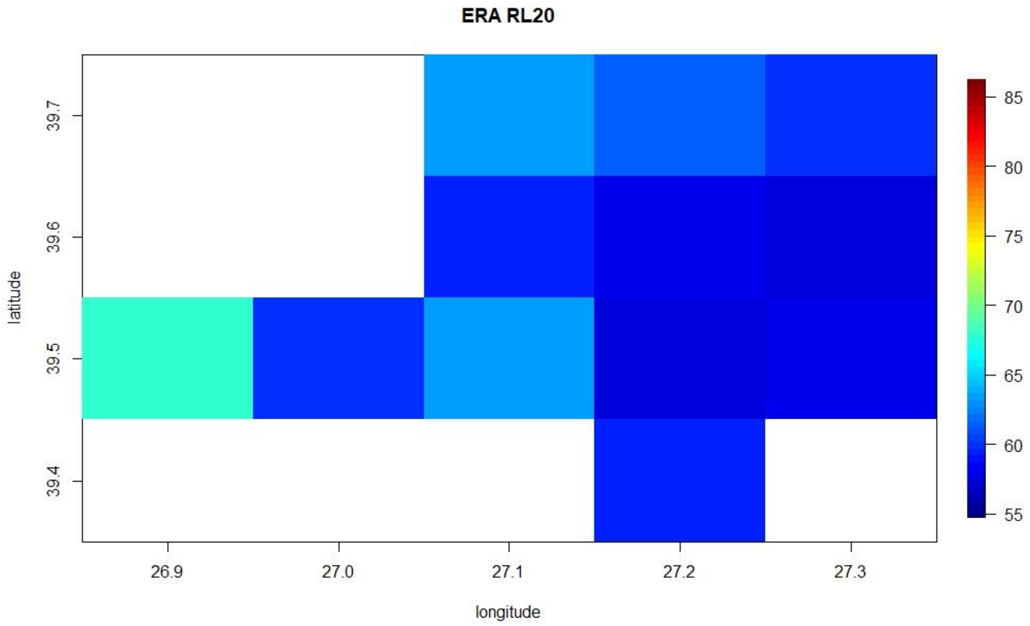


Figure 3.11 ERA5-Land maximum precipitation values for 20 years return level

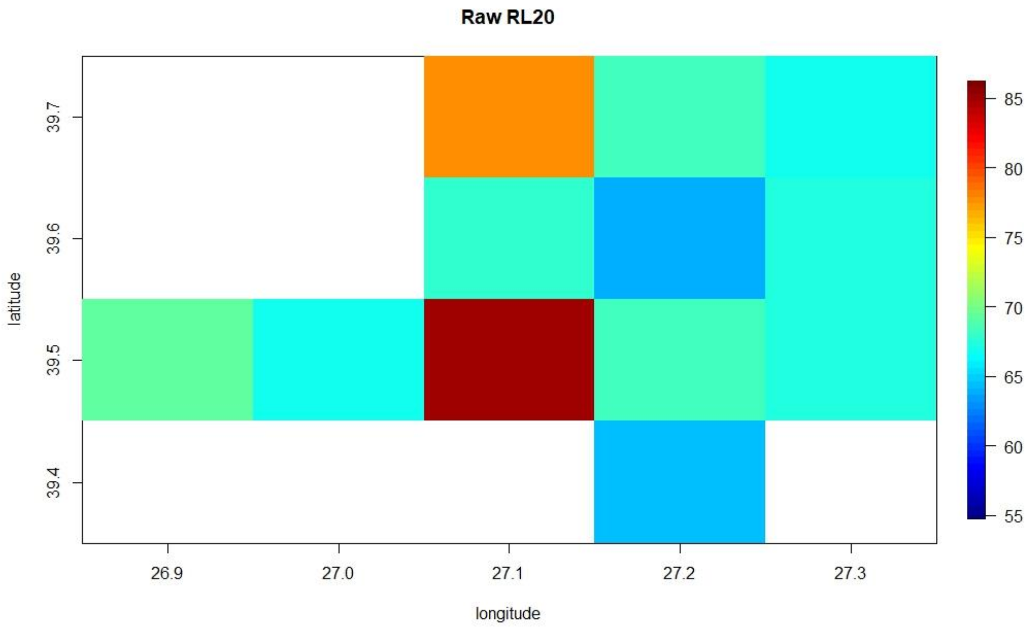


Figure 3.12 Raw GCMs maximum precipitation values for 20 years return level

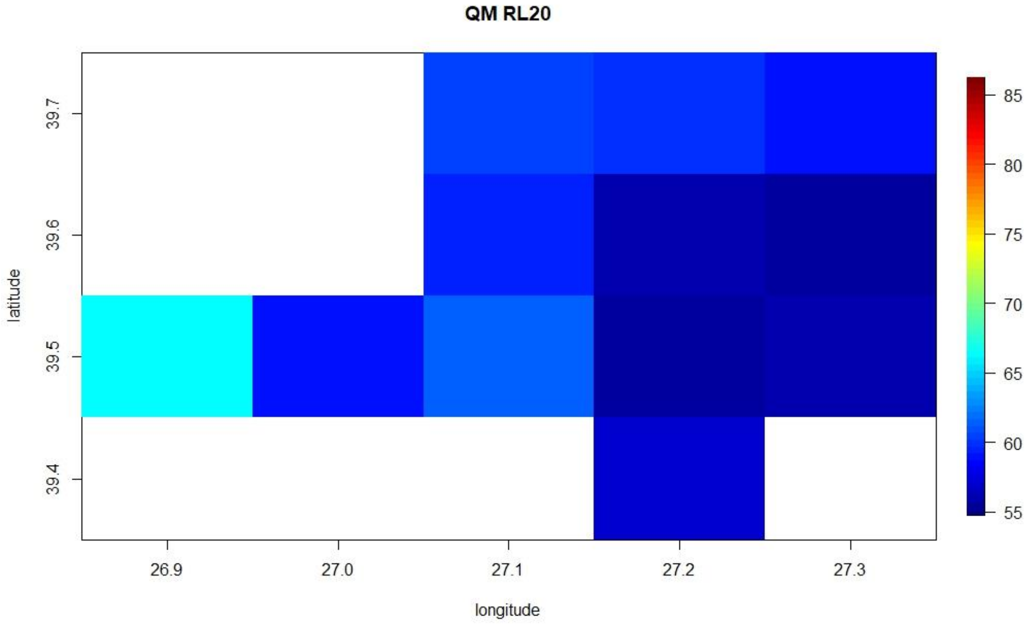


Figure 3.13 QM bias corrected maximum precipitation values for 20 years return level

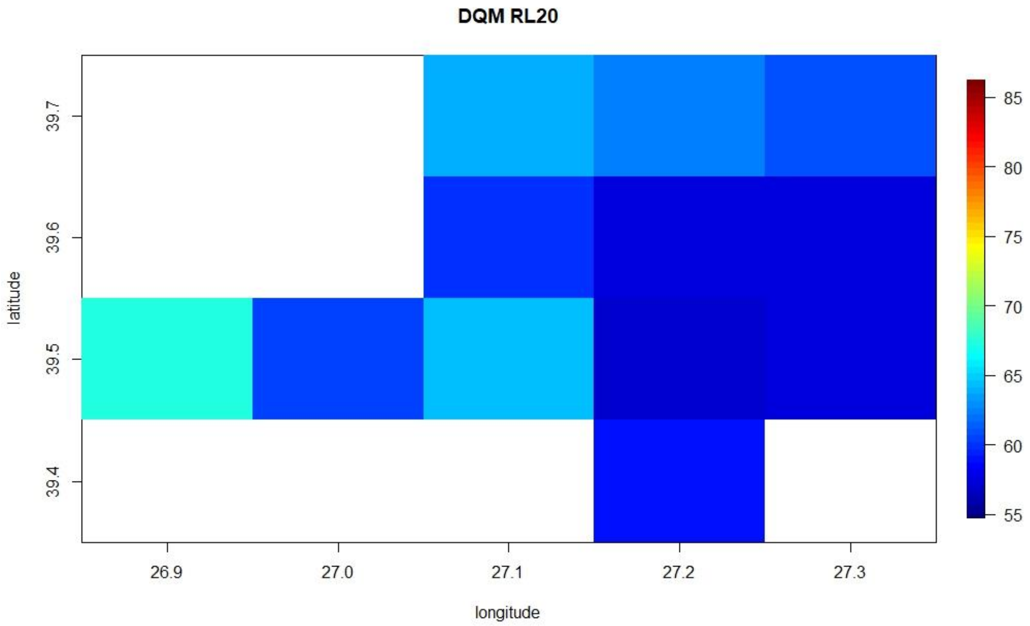


Figure 3.14 DQM bias corrected maximum precipitation values for 20 years return level

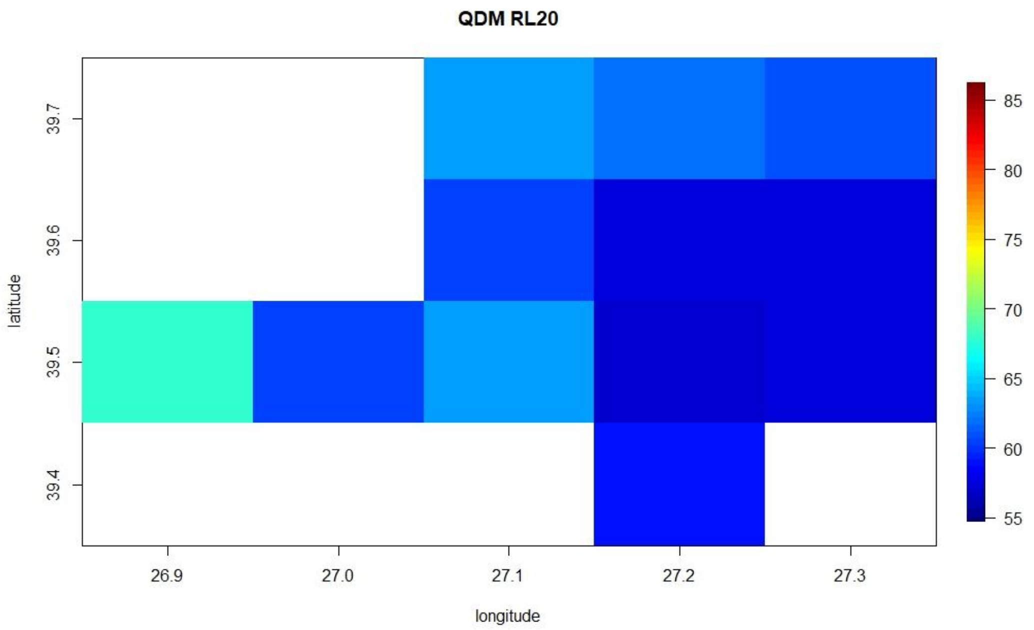


Figure 3.15 QDM bias corrected maximum precipitation values for 20 years return level

3.2 Evaluation of Precipitation Data

3.2.1 Historical Period

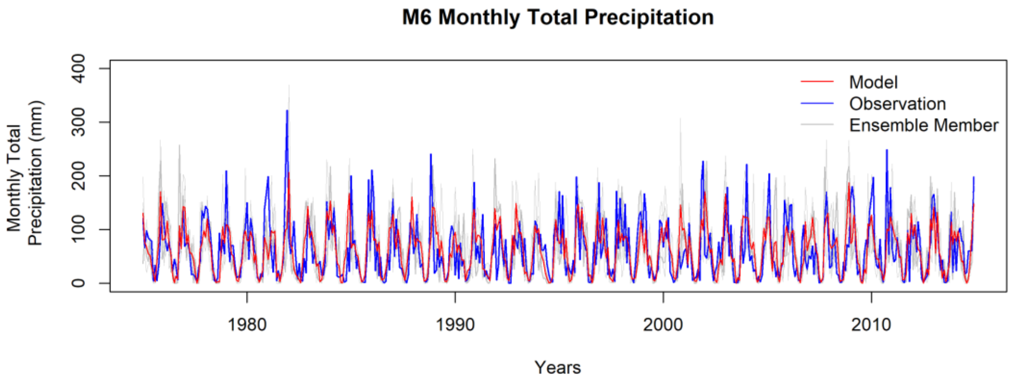
Model statistics for monthly precipitation values of each subbasin are presented in Table 3.5. In individual model precipitation inputs (M1-M5) RMSE values are higher compared to ensemble model inputs (M6-M9). Correlation coefficients are higher with the ensemble inputs in comparison with individual model inputs.

Table 3.5 Correlation Coefficient (r) and RMSE values of precipitation output from each model scenario

	G03		G12		G18		N14		N15	
	r	RMSE	r	RMSE	r	RMSE	r	RMSE	r	RMSE
M1	0.49	54.29	0.49	56.66	0.49	59.5	0.49	57.91	0.51	62.53
M2	0.46	55.86	0.46	58.41	0.46	61.39	0.46	59.65	0.49	63.66
M3	0.49	55.93	0.48	58.54	0.48	61.63	0.48	59.85	0.48	65.19
M4	0.53	52.83	0.53	55.52	0.52	58.50	0.54	56.21	0.54	61.08
M5	0.45	55.43	0.44	57.91	0.44	60.83	0.45	59.21	0.45	64.42
M6	0.60	43.75	0.60	45.68	0.60	48.16	0.61	47.20	0.62	51.49
M7	0.63	42.36	0.62	44.32	0.62	46.76	0.63	45.69	0.64	49.93
M8	0.63	41.62	0.63	43.38	0.63	45.78	0.64	45.05	0.65	49.37
M9	0.65	40.53	0.65	42.28	0.65	44.65	0.66	43.97	0.67	48.29

Through Figure 3.16 - Figure 3.20 monthly total precipitation for each subbasin time series plots are presented. Model and observation results are denoted with red and blue colors respectively and grey colored plots show all other model scenarios.

Overall, both M6 and M8 model ensemble can represent peak precipitation values. It is seen from Figure 3.16 - Figure 3.20 that in many years M6 is underestimating the peak precipitations in some months whereas M8 is more likely to overestimate in some months. However, M8 model can represent the observations better in comparison to M6 model ensemble.



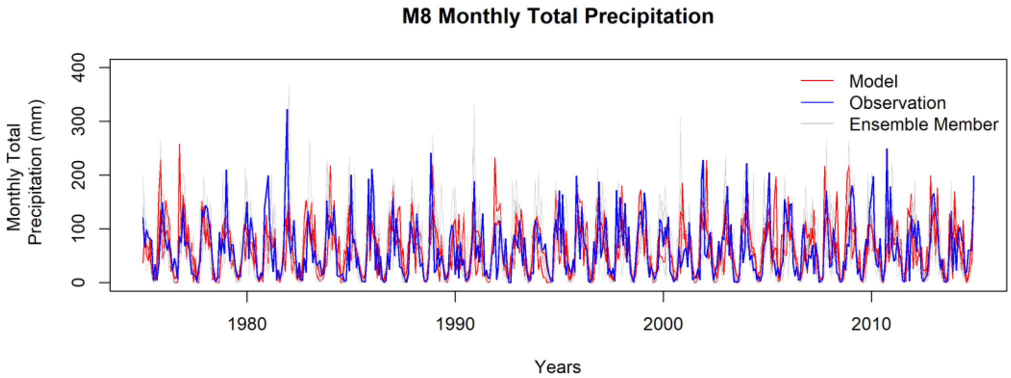


Figure 3.16 G03 subbasin monthly mean precipitation for M6 and M8 model scenario

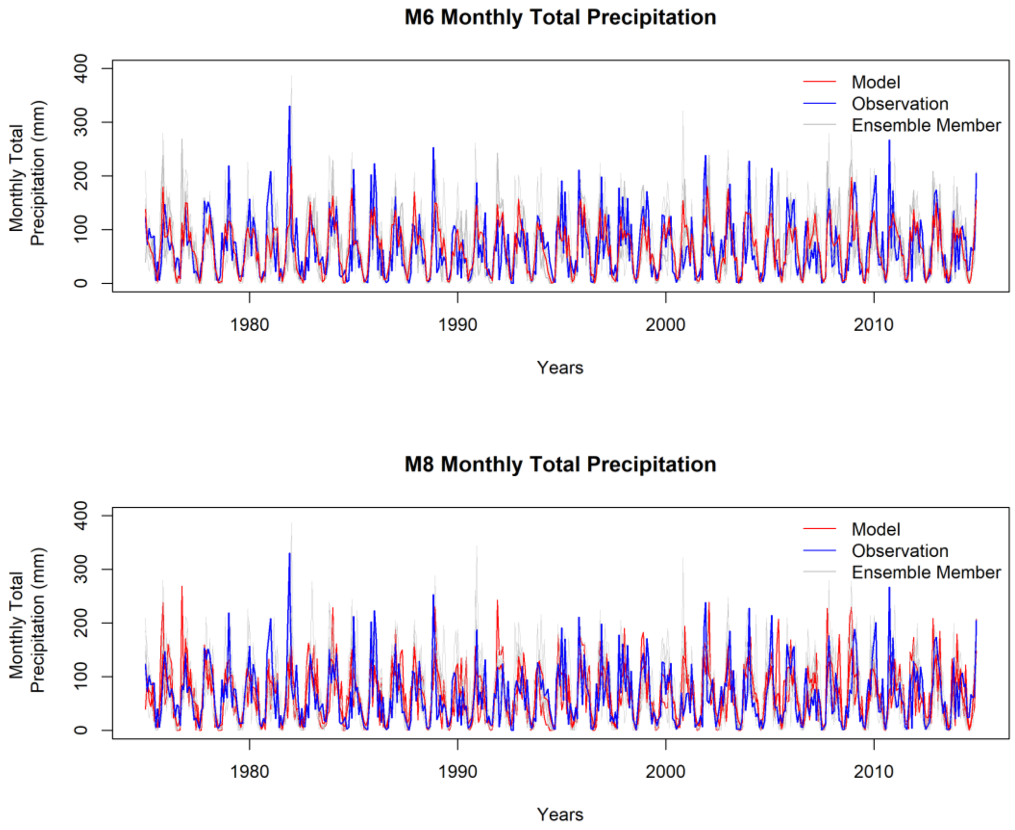
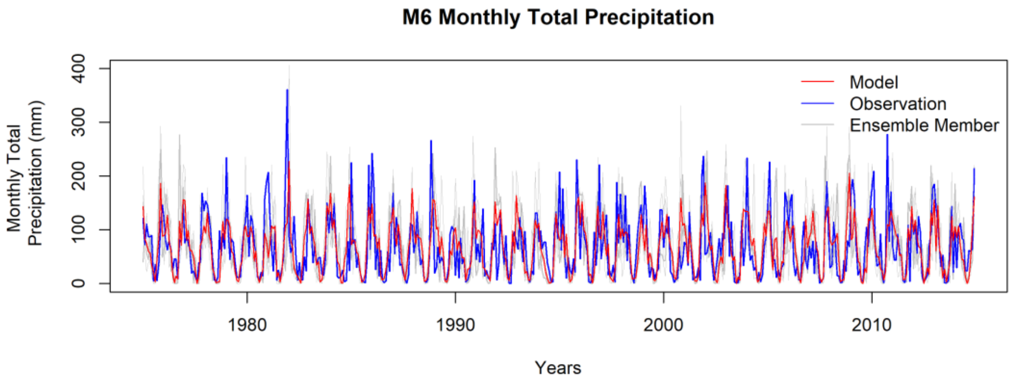


Figure 3.17 G12 subbasin monthly mean precipitation for M6 and M8 model scenario



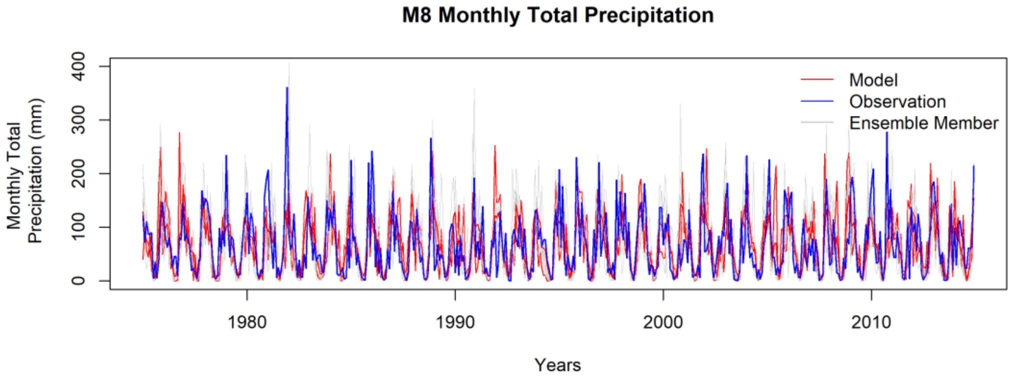


Figure 3.18 G18 subbasin monthly mean precipitation for M6 and M8 model scenario

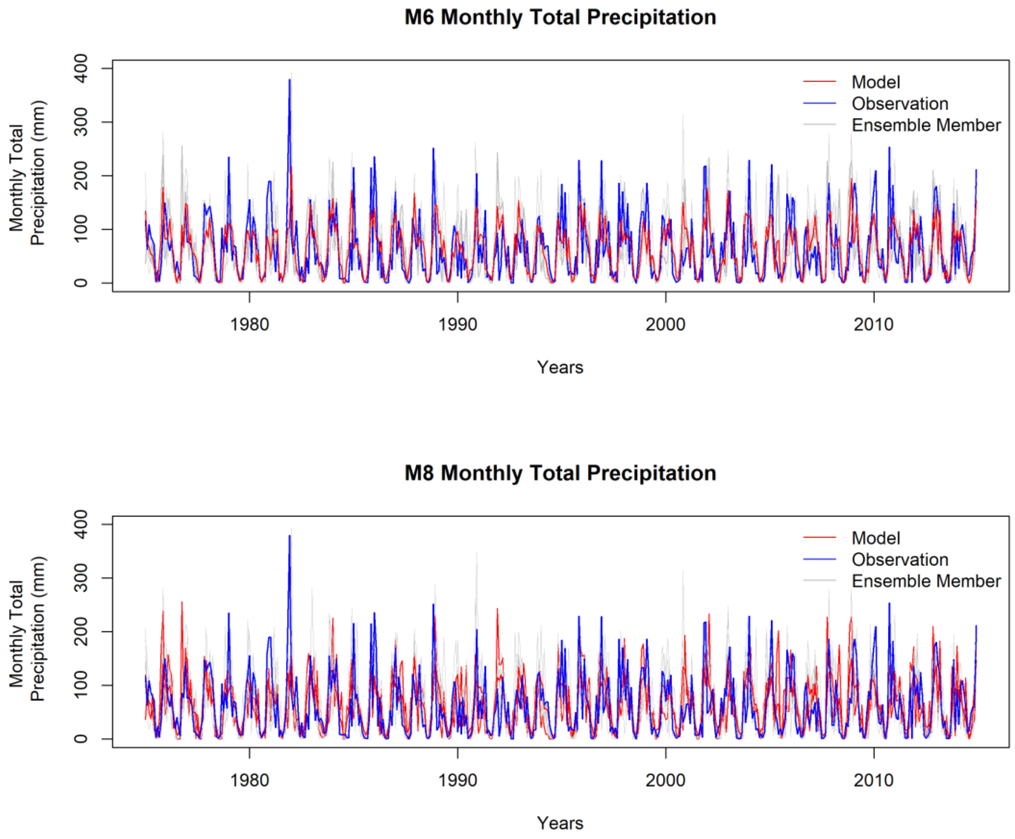
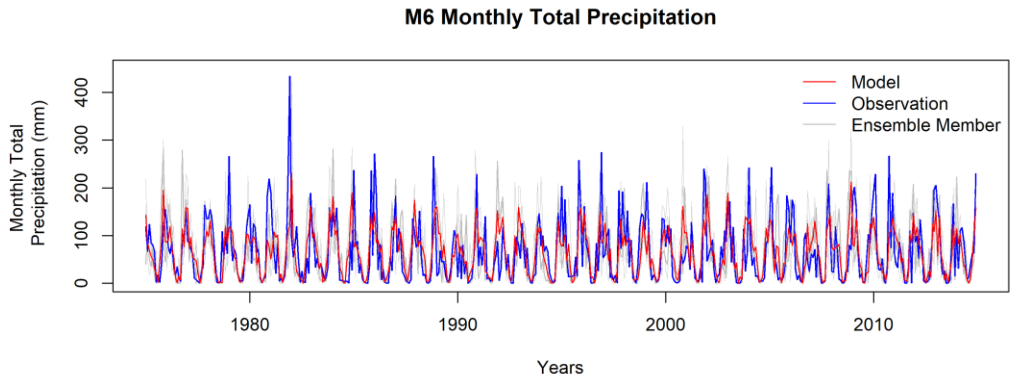


Figure 3.19 N14 subbasin monthly mean precipitation for M6 and M8 model scenario



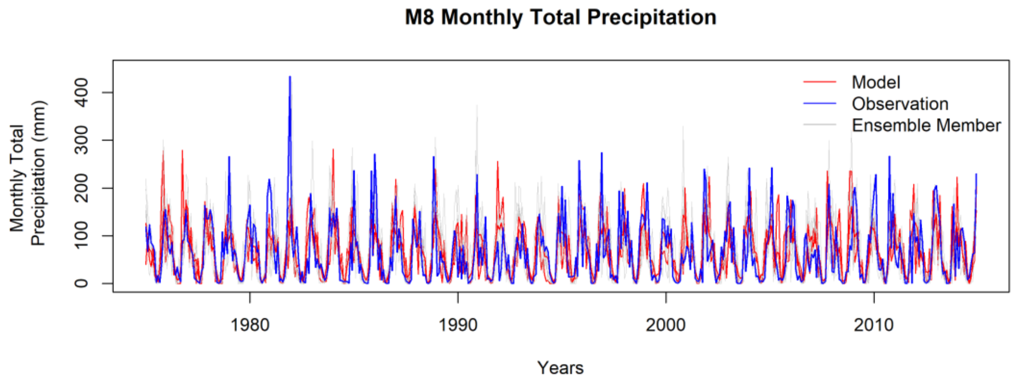


Figure 3.20 N15 subbasin monthly mean precipitation for M6 and M8 model scenario

From Figure 3.21 to Figure 3.25, interquartile range of the M8 model ensemble for annual total precipitation is presented along with the ERA5 observations for each subbasin.

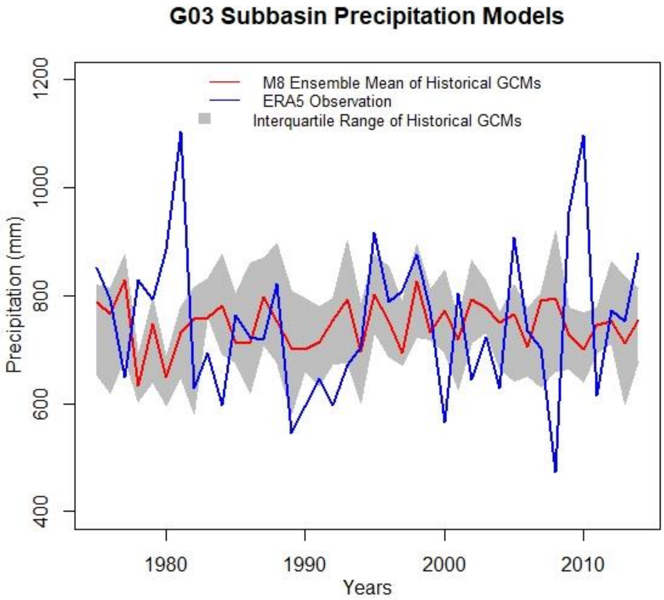


Figure 3.21 G03 subbasin annual historical precipitation values with ERA5 observations and GCM data

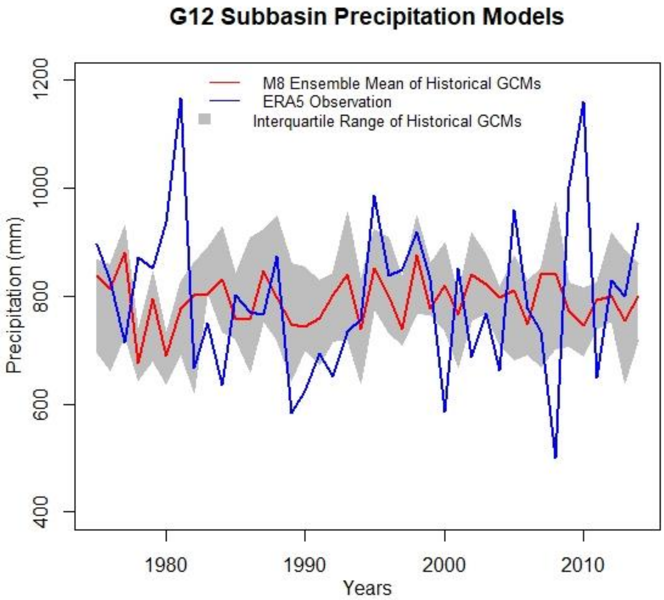


Figure 3.22 G12 subbasin annual historical precipitation values with ERA5 observations and GCM data

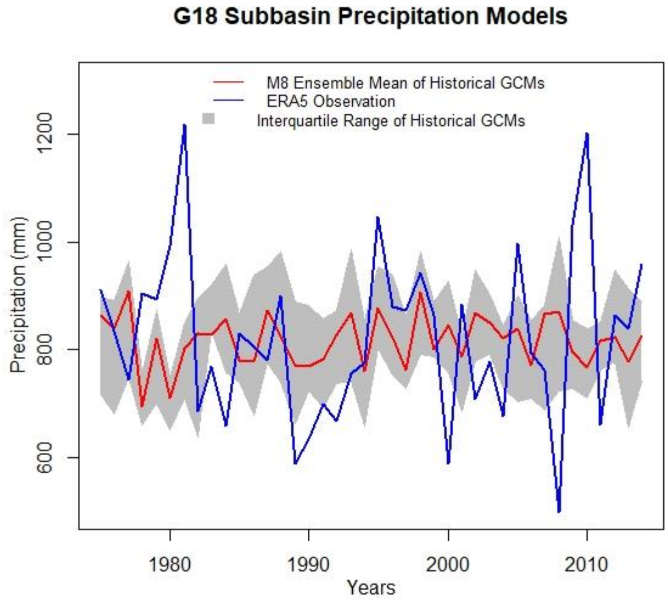


Figure 3.23 G18 subbasin annual historical precipitation values with ERA5 observations and GCM data

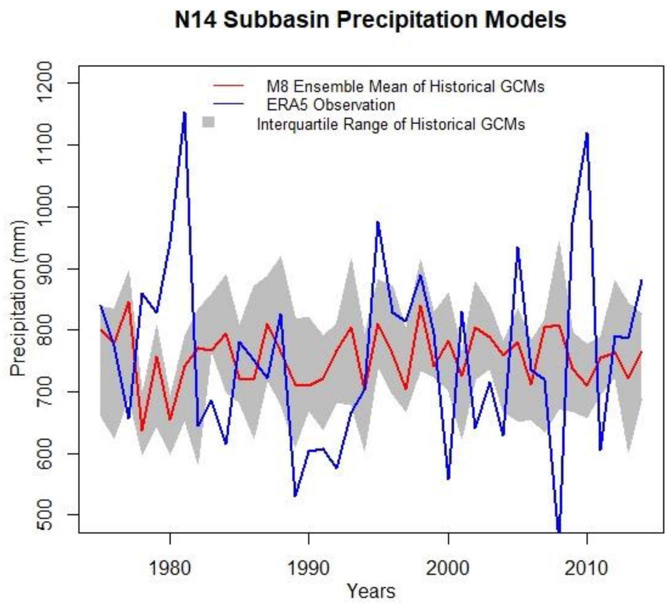


Figure 3.24 N14 subbasin annual historical precipitation values with ERA5 observations and GCM data

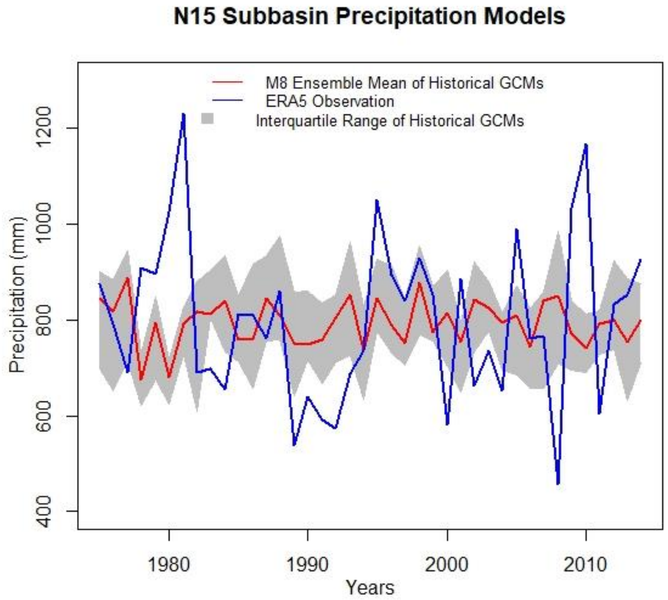


Figure 3.25 N15 subbasin annual historical precipitation values with ERA5 observations and GCM data

3.2.2 Future Period

Seasonal and annual percent changes in each subbasin with respect to historical period are presented in Table 3.6 - Table 3.10 for each subbasin. Percent changes are calculated with the percent difference between historical period and future periods. Also, annual plots for total precipitation of each basin are presented in Figure 3.26 - Figure 3.30. Each subbasin is examined respectively.

G03 Subbasin

In M6 model SSP2-4.5 scenario, Spring precipitation values are decreasing except for the slight increase in the far future period. Summer precipitations are decreasing overall. In Autumn and Winter seasons there is an increase in precipitation values. In the annual basis, it is seen that in the near and far future periods precipitation values are slightly increasing while in the mid future a decrease in precipitation is observed. SSP5-8.5 scenario suggests decrease in all seasons and future periods. It is seen that the percent decrease is higher in the far future periods of all seasons.

In M8 ensemble precipitation in both SSP2-4.5 and SSP5-8.5 scenario precipitation values are decreasing overall in all periods and all seasons.

In most of the seasons, although the percent changes are very small, the direction of change is shifted between M6 and M8 especially in SSP2-4.5 scenario far future period.

Table 3.6 Seasonal and annual precipitation changes in G03 subbasin with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)
Spring	208.9	204.2	200.2	210.0	208.6	198.4	171.6	200.0	195.2	191.1	193.3	200.8	191.7	169.1
	%	-2.25	-4.16	0.52	-0.14	-5.03	-17.84	%	-2.44	-4.46	-3.35	0.36	-4.17	-15.46
Summer	46.9	42.6	37.2	37.5	40.8	30.4	24.8	56.0	56.1	47.5	46.1	50.4	40.2	33.4
	%	-9.2	-20.78	-20.19	-12.99	-35.32	-47.16	%	0.24	-15.09	-17.64	-9.97	-28.13	-40.29
Autumn	183.2	187.0	183.9	187.5	177.8	163.0	156.3	182.8	176.2	174.4	175.3	175.5	158.0	145.0
	%	2.08	0.37	2.35	-2.97	-11.01	-14.69	%	-3.59	-4.6	-4.1	-4	-13.58	-20.68
Winter	307.0	314.8	311.7	318.9	306.2	305.8	272.3	307.2	307.5	304.2	304.0	305.3	288.2	277.8
	%	2.54	1.54	3.89	-0.26	-0.38	-11.31	%	0.07	-0.99	-1.05	-0.64	-6.19	-9.58
Annual	746.1	748.7	733.0	753.9	733.4	697.6	625.0	746.0	735.0	717.2	718.7	731.9	678.1	625.3
	%	0.35	-1.75	1.05	-1.69	-6.49	-16.22	%	-1.48	-3.86	-3.66	-1.89	-9.11	-16.18

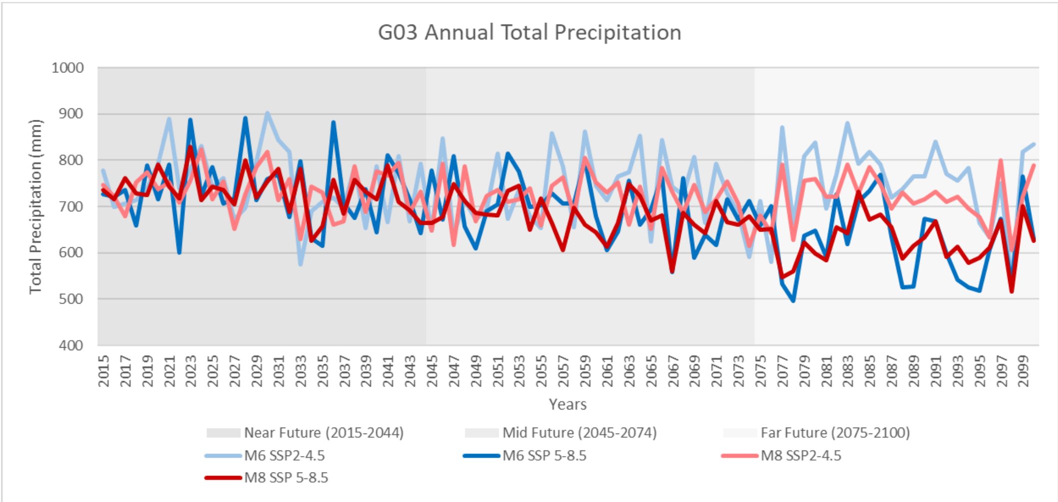


Figure 3.26 G03 subbasin annual total precipitation in SSP2-4.5 and SSP5-8.5 scenarios

G12 Subbasin

In G12 subbasin M6 model SSP2-4.5 scenario suggests decrease in spring and summer precipitation while there is an increase in autumn and winter precipitations. It should be noted that percent decrease amounts are very low. The same model ensemble SSP5-8.5 scenario shows decreasing precipitation values on seasonal and annual basis. M8 scenario suggests decrease in all future periods and seasons and it is seen that the amount of decrease gets higher as we move from the near future to the far future. When M6 and M8 model ensembles are compared, from M6 to M8, the direction of change is shifted from increasing to decreasing in SSP2-4.5 scenario.

Table 3.7 Seasonal and annual precipitation changes in G12 subbasin with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)
Spring	222.6	216.8	212.7	222.9	221.1	210.2	181.8	213.3	207.3	203.1	205.5	213.0	203.2	179.2
	%	-2.59	-4.45	0.16	-0.66	-5.56	-18.32	%	-2.78	-4.78	-3.64	-0.15	-4.73	-15.98
Summer	50.4	45.7	39.8	40.1	43.6	32.5	26.6	60.2	60.0	50.8	49.3	53.8	43.0	35.7
	%	-9.46	-21.12	-20.46	-13.56	-35.54	-47.33	%	-0.29	-15.56	-18.05	-10.55	-28.48	-40.64
Autumn	194.0	197.5	194.2	197.8	187.7	172.1	164.8	193.5	186.3	184.2	185.0	185.3	166.8	153.0
	%	1.82	0.13	1.99	-3.24	-11.26	-15.03	%	-3.73	-4.78	-4.37	-4.25	-13.79	-20.95
Winter	325.7	333.2	329.9	337.3	323.6	322.9	287.5	325.6	325.1	321.7	321.4	322.4	304.4	293.1
	%	2.3	1.3	3.57	-0.63	-0.84	-11.73	%	-0.16	-1.22	-1.29	-0.98	-6.53	-9.98
Annual	792.6	793.1	776.5	798.1	776.0	737.7	660.6	792.6	778.7	759.8	761.3	774.5	717.4	661.0
	%	0.06	-2.03	0.7	-2.1	-6.92	-16.65	%	-1.75	-4.13	-3.95	-2.28	-9.48	-16.6

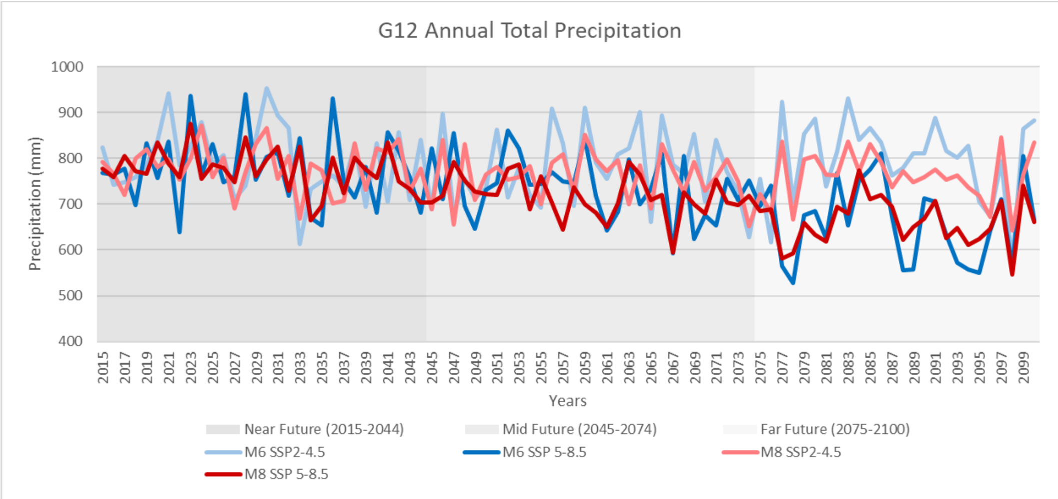


Figure 3.27 G12 subbasin annual total precipitation in SSP2-4.5 and SSP5-8.5 scenarios

G18 subbasin

M6 model ensemble suggests increase in seasonal precipitation for autumn and winter in SSP2-4.5 scenario. In M8, in near future SSP2-4.5 scenario of summer months direction of change is shifted from decreasing to slightly increasing when compared to M6 model ensemble. In G18 subbasin in both M6 and M8 ensemble precipitation there is percent decrease in all seasons for SSP5-8.5 scenarios.

Table 3.8 Seasonal and annual precipitation changes in G18 subbasin with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)
Spring	228.8	223.7	219.3	230.0	228.3	217.3	188.0	219.1	213.8	209.4	211.7	219.9	210.0	185.3
	%	-2.26	-4.14	0.5	-0.22	-5.03	-17.82	%	-2.44	-4.45	-3.38	0.33	-4.17	-15.44
Summer	51.4	46.7	40.7	41.0	44.7	33.2	27.1	61.3	61.4	52.0	50.4	55.1	44.0	36.6
	%	-9.18	-20.79	-20.23	-13.04	-35.35	-47.25	%	0.24	-15.16	-17.73	-10.07	-28.16	-40.32
Autumn	200.5	204.7	201.3	205.4	194.7	178.4	171.2	200.1	192.9	190.9	191.8	192.2	172.9	158.7
	%	2.08	0.38	2.44	-2.91	-11.04	-14.63	%	-3.58	-4.58	-4.13	-3.94	-13.58	-20.68
Winter	336.5	345.1	341.6	349.6	335.7	335.3	298.5	336.7	337.0	333.4	333.4	334.6	315.9	304.5
	%	2.55	1.5	3.89	-0.26	-0.38	-11.31	%	0.07	-1	-1	-0.62	-6.2	-9.57
Annual	817.3	820.2	802.9	826.0	803.4	764.2	684.8	817.2	805.1	785.7	787.3	801.8	742.8	685.1
	%	0.35	-1.76	1.07	-1.7	-6.49	-16.2	%	-1.49	-3.86	-3.66	-1.89	-9.11	-16.17

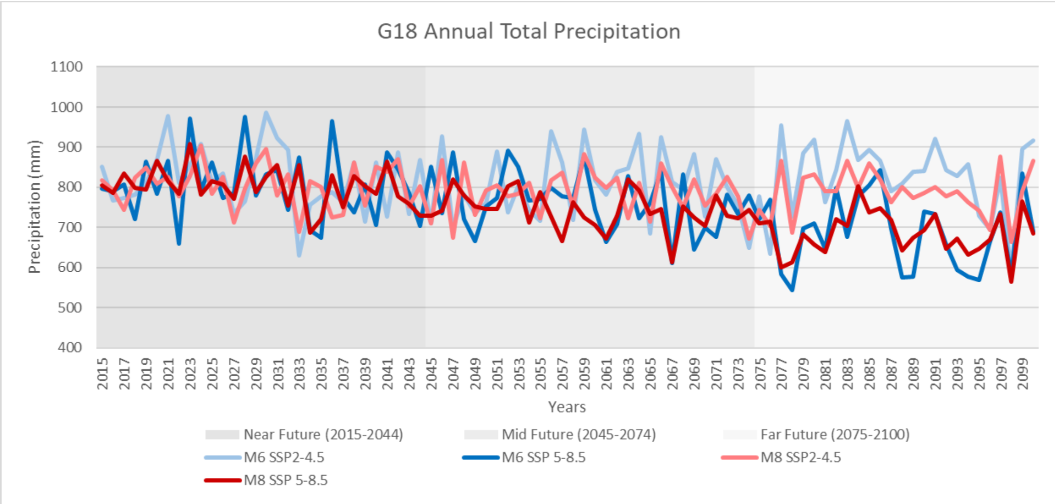


Figure 3.28 G18 subbasin annual total precipitation in SSP2-4.5 and SSP5-8.5 scenarios

N14 Subbasin

In N14 subbasin, M6 model ensemble suggests a percent decrease in spring and summer months and increase in autumn and winter months in all future periods. In SSP5-8.5 scenario, percent decrease amount is larger especially in summer months. M8 model ensemble overall estimates decrease in seasonal precipitation except for the slight increase in summer and winter months in near future for SSP2-4.5 scenario and spring and winter precipitation in near future for SSP5-8.5

Table 3.9 Seasonal and annual precipitation changes in N14 subbasin with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)
Spring	210.3	207.3	203.4	213.4	212.8	202.7	175.6	201.1	197.9	193.9	195.7	204.5	195.6	172.8
	%	-1.42	-3.31	1.46	1.17	-3.62	-16.53	%	-1.58	-3.58	-2.66	1.72	-2.69	-14.08
Summer	46.2	42.2	37.0	37.2	40.8	30.1	24.6	54.9	55.9	47.2	45.8	50.2	39.9	33.4
	%	-8.57	-20	-19.44	-11.73	-34.89	-46.67	%	1.71	-14.05	-16.64	-8.61	-27.31	-39.27
Autumn	186.9	192.2	188.7	193.4	182.9	167.6	160.8	186.7	180.7	178.9	180.2	180.5	162.3	148.9
	%	2.84	0.96	3.46	-2.17	-10.35	-13.97	%	-3.19	-4.18	-3.46	-3.3	-13.04	-20.23
Winter	312.9	322.7	319.3	327.8	315.3	315.6	280.7	313.6	315.7	312.3	312.7	314.7	297.1	286.8
	%	3.15	2.07	4.77	0.78	0.87	-10.29	%	0.66	-0.41	-0.31	0.34	-5.26	-8.56
Annual	756.3	764.6	748.4	771.8	751.8	716.0	641.7	756.3	750.2	732.3	734.4	749.9	695.0	641.8
	%	1.09	-1.05	2.05	-0.61	-5.33	-15.15	%	-0.81	-3.17	-2.9	-0.84	-8.1	-15.14

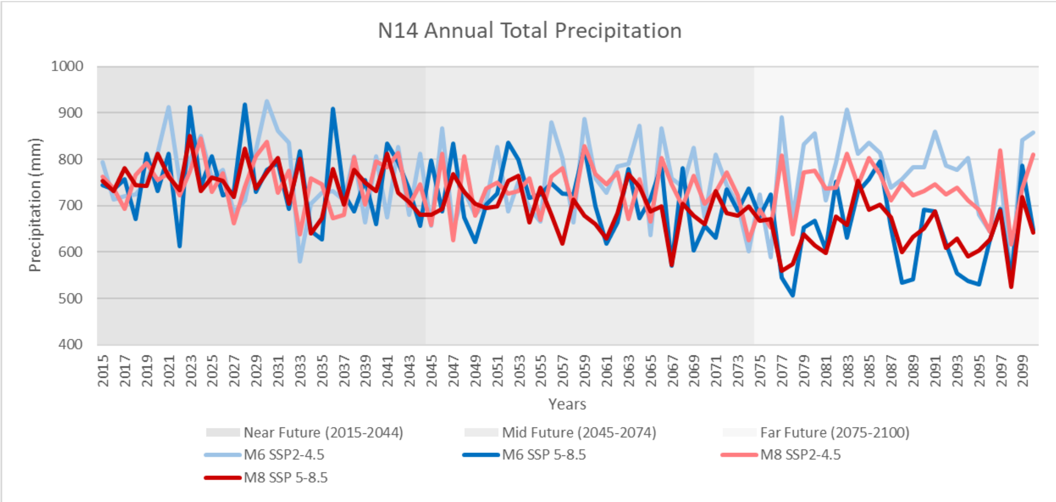


Figure 3.29 N14 subbasin annual total precipitation in SSP2-4.5 and SSP5-8.5 scenarios

__N15 Subbasin__

In N15 subbasin, spring and summer precipitation values are decreasing in both scenarios overall except for a slight increase in near future with SSP5-8.5 scenario of M6 model ensemble. In autumn and winter there is a percent increase in SSP2-4.5 scenario whereas in autumn change is in negative direction with SSP5-8.5 scenario. M8 ensemble differs from M6 in summer months of near future period with SSP2-4.5 where direction of change is shifted to percent increase. Overall, in M8 model ensemble, percent decrease is dominating with all scenarios. There is a percent increase in precipitation in only near future period for spring season.

Table 3.10 Seasonal and annual precipitation changes in N15 subbasin with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)	H	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)
Spring	214.4	210.5	206.8	214.2	215.7	205.5	176.1	207.1	204.0	200.1	200.1	211.0	202.0	177.6
	%	-1.82	-3.54	-0.1	0.62	-4.12	-17.85	%	-1.5	-3.4	-3.38	1.89	-2.47	-14.27
Summer	43.3	39.9	34.6	35.2	38.4	27.9	24.1	54.3	56.0	47.0	45.7	50.1	39.7	34.0
	%	-7.98	-20.05	-18.65	-11.43	-35.57	-44.31	%	3.16	-13.38	-15.8	-7.78	-26.85	-37.47
Autumn	201.3	208.1	201.3	208.3	198.4	179.7	175.1	198.9	193.3	189.9	192.3	193.4	172.8	159.8
	%	3.39	-0.02	3.46	-1.47	-10.75	-13.04	%	-2.82	-4.53	-3.33	-2.74	-13.11	-19.65
Winter	334.2	343.2	340.2	348.0	340.1	339.7	301.4	332.8	334.9	331.7	331.5	336.6	317.4	306.2
	%	2.7	1.81	4.13	1.77	1.66	-9.81	%	0.64	-0.33	-0.41	1.15	-4.64	-8.01
Annual	793.2	801.7	782.9	805.7	792.5	752.8	676.7	793.1	788.2	768.7	769.6	791.2	731.9	677.5
	%	1.07	-1.29	1.58	-0.08	-5.08	-14.69	%	-0.62	-3.08	-2.97	-0.25	-7.72	-14.58

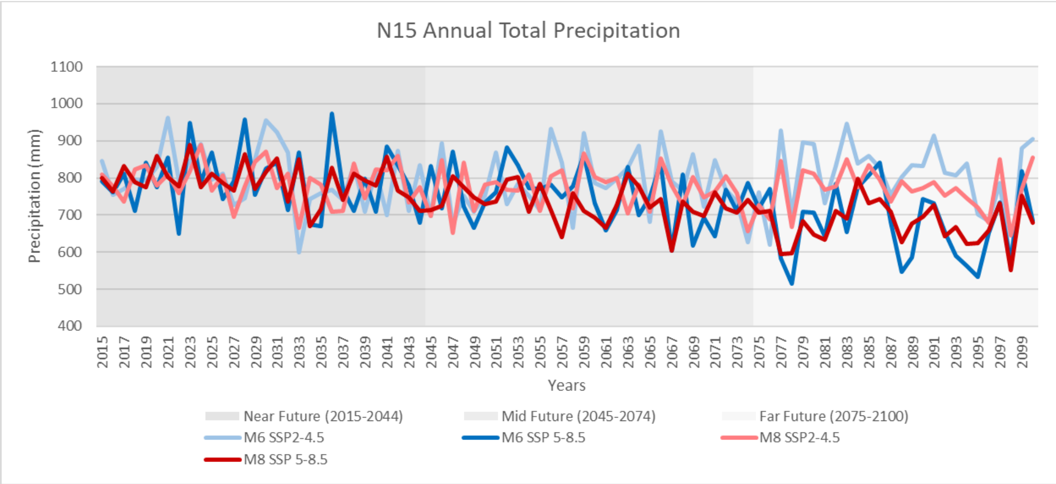


Figure 3.30 N15 subbasin annual total precipitation in SSP2-4.5 and SSP5-8.5 scenarios

Percent changes in each subbasin can be visualized in Figure 3.31 and Figure 3.32 for M8 model ensemble SSP2-4.5 and SSP5-8.5 scenarios respectively.

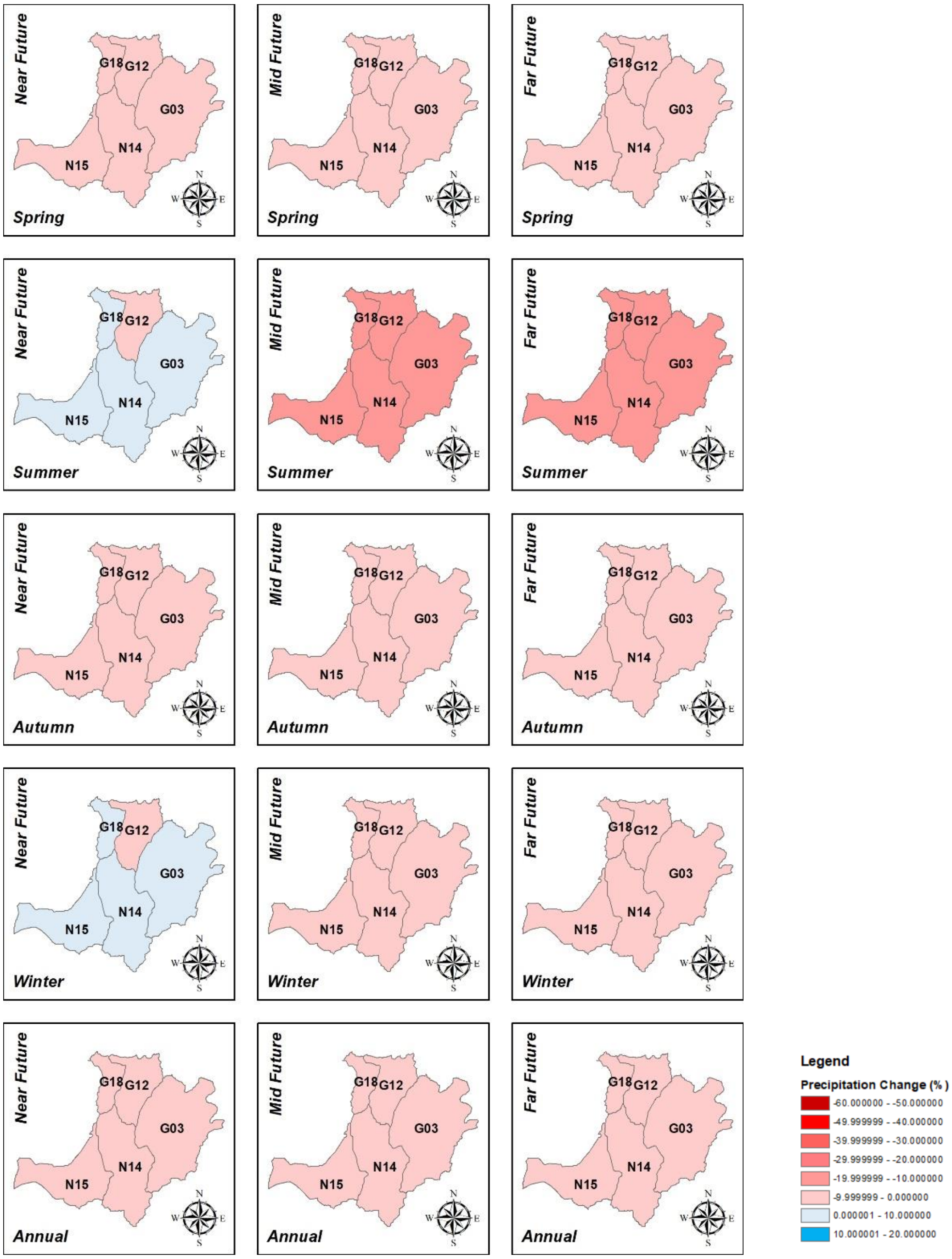


Figure 3.31 Seasonal precipitation changes with respect to historical period in each subbasin – SSP2-4.5 scenario

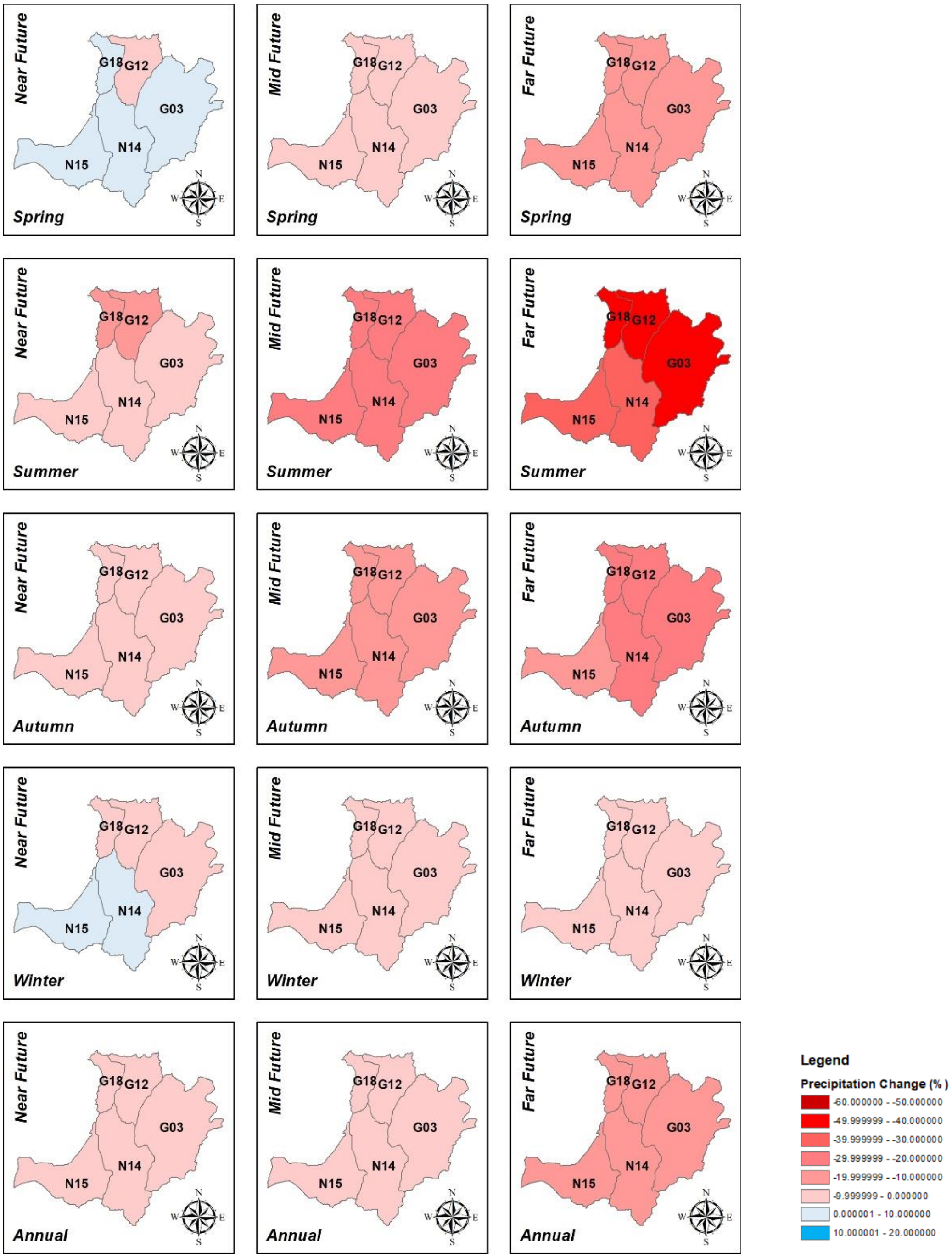


Figure 3.32 Seasonal precipitation changes with respect to historical period in each subbasin – SSP5-8.5 scenario

3.2.3 Trend Analysis

Trends in M8 precipitation are calculated for historical period and three future periods for each scenario (SSP2-4.5 and SSP5-8.5).

Trend test results for each subbasin are presented in Appendix – C on monthly, seasonal and annual basis. Seasonal trends in each subbasin are given in Figure 3.33 and Figure 3.34. In the historical period summer precipitation values are significantly increasing. It is seen that the increasing trend is consistent within all subbasins whereas in the north subbasins increase is more pronounced.

Within the projected period, precipitation in spring is significantly decreasing with SSP2-4.5 scenario in mid future period. It can be seen that the decrease is consistent within all subbasins. There is a significant decrease in autumn precipitation for SSP5-8.5 scenario within all subbasins.

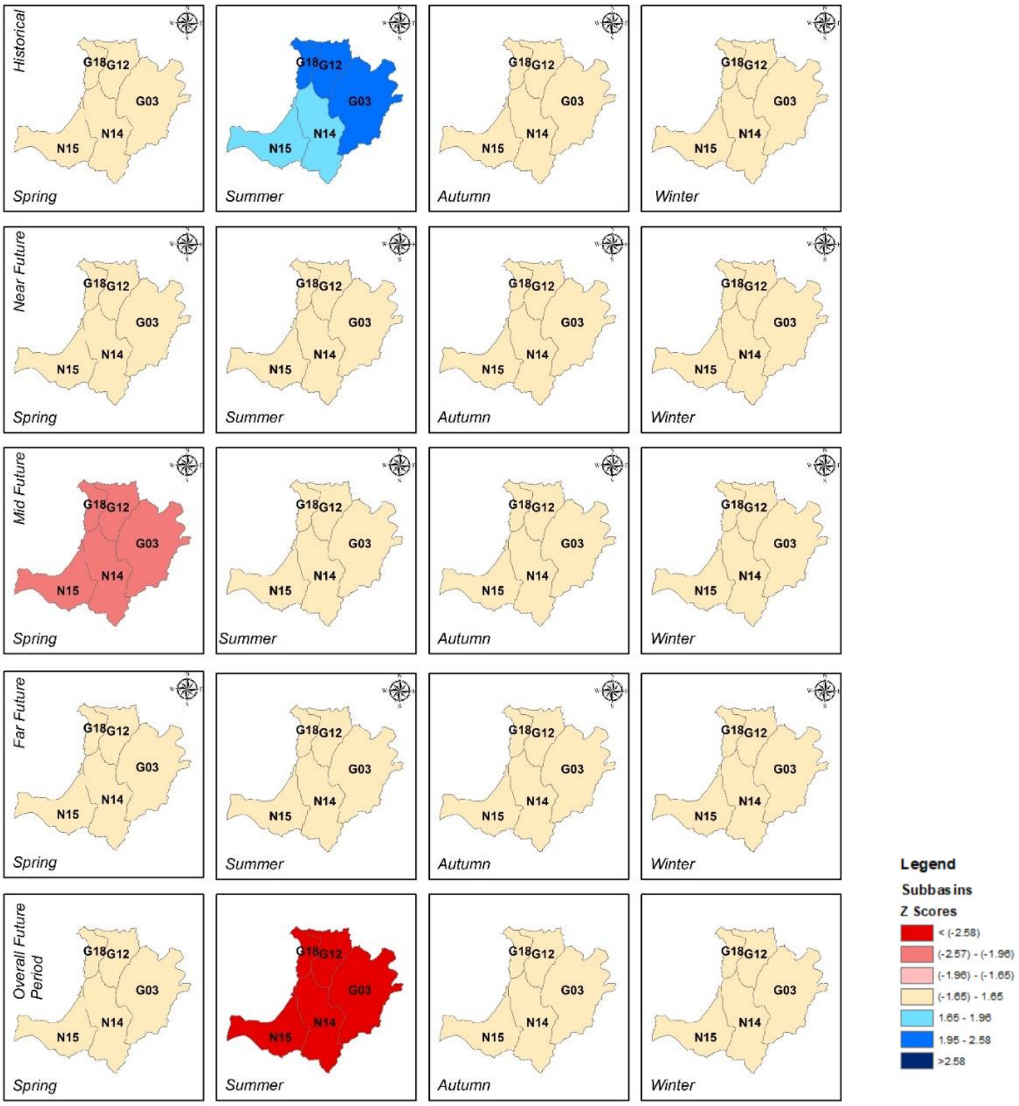


Figure 3.33 Seasonal precipitation trends in subbasins for SSP2-4.5 scenario

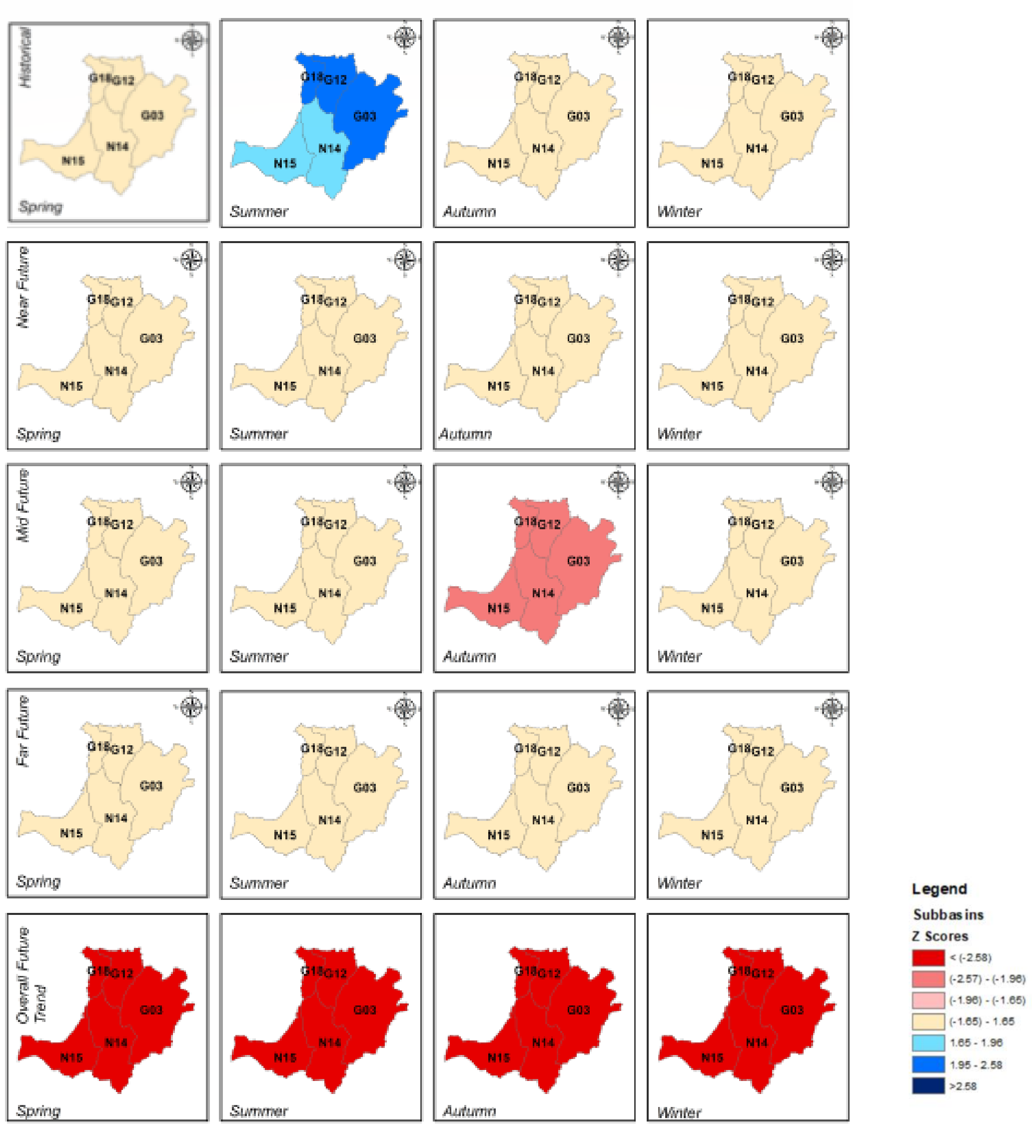


Figure 3.34 Seasonal precipitation trends in subbasins for SSP2-8.5 scenario

3.3 Evaluation of Temperature Data

3.3.1 Historical Period

Model statistics for monthly temperature values of each basin are presented in Table 3.11. Modeled temperature data is compared with observational data using RMSE and r metrics for each subbasin. RMSE values are higher with individual model inputs (M1-M5) in comparison to ensemble model inputs (M6-M9). Correlation coefficients are higher with the ensemble inputs than with individual model inputs.

Table 3.11 Correlation Coefficient (r) and RMSE values of temperature output from each model scenario

	G03		**G12**		**G18**		**N14**		**N15**	
	r	**RMSE**	**r**	**RMSE**	**r**	**RMSE**	**r**	**RMSE**	**r**	**RMSE**
M1	0.96	2.10	0.96	2.13	0.96	2.12	0.96	2.16	0.96	2.56
M2	0.96	2.11	0.96	2.15	0.96	2.13	0.96	2.17	0.96	2.57
M3	0.94	2.39	0.94	2.42	0.94	2.41	0.95	2.44	0.95	2.82
M4	0.95	2.24	0.95	2.28	0.95	2.26	0.95	2.29	0.95	2.70
M5	0.96	2.15	0.95	2.18	0.95	2.16	0.96	2.20	0.96	2.62
M6	0.97	1.66	0.97	1.69	0.97	1.67	0.97	1.73	0.97	2.25
M7	0.97	1.65	0.97	1.68	0.97	1.66	0.97	1.72	0.97	2.24
M8	0.98	1.58	0.97	1.61	0.98	1.58	0.97	1.76	0.98	2.19
M9	0.98	1.57	0.97	1.60	0.98	1.58	0.97	1.74	0.98	2.18

Through Figure 3.35 - Figure 3.39 monthly mean temperature for each subbasin time series plots are presented. Model and observation results are denoted with red and blue colors respectively and grey colored plots show ensemble members.

From Figure 3.35 to Figure 3.39 both model ensembles represent the annual cycle of temperature values where M8 ensemble underestimates in months with warmer temperatures and M6 model ensemble overestimates in colder months overall.

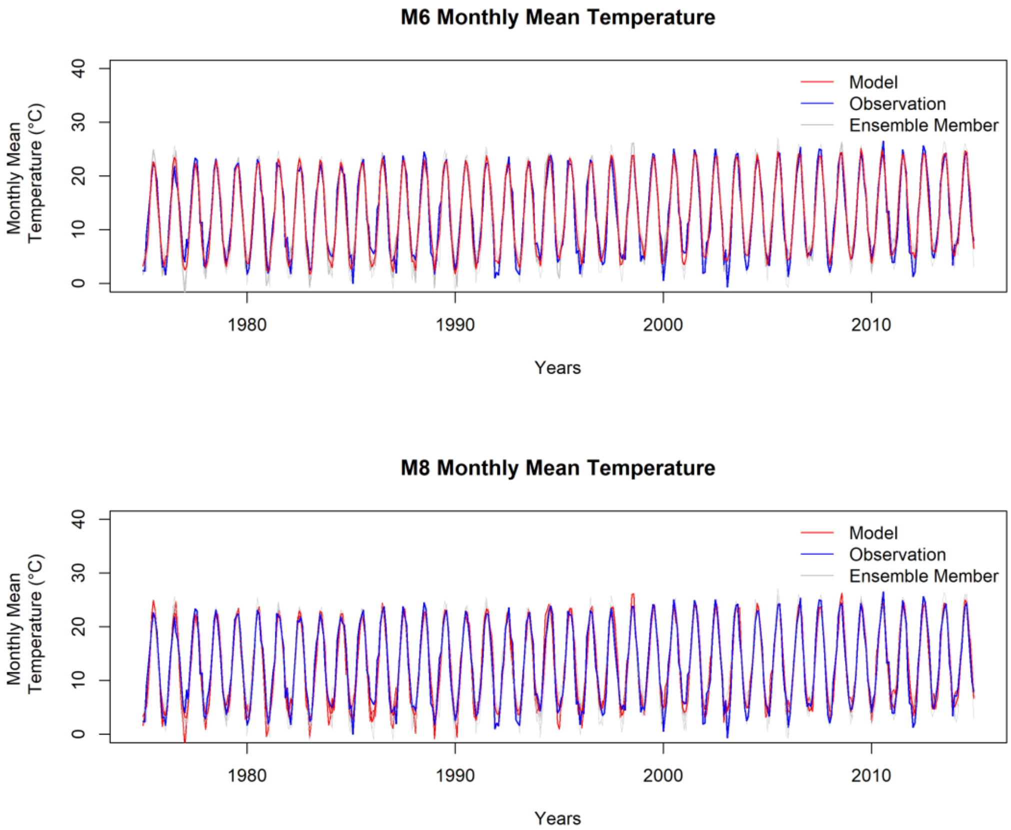


Figure 3.35 G03 subbasin monthly mean temperature for M6 and M8 model scenario

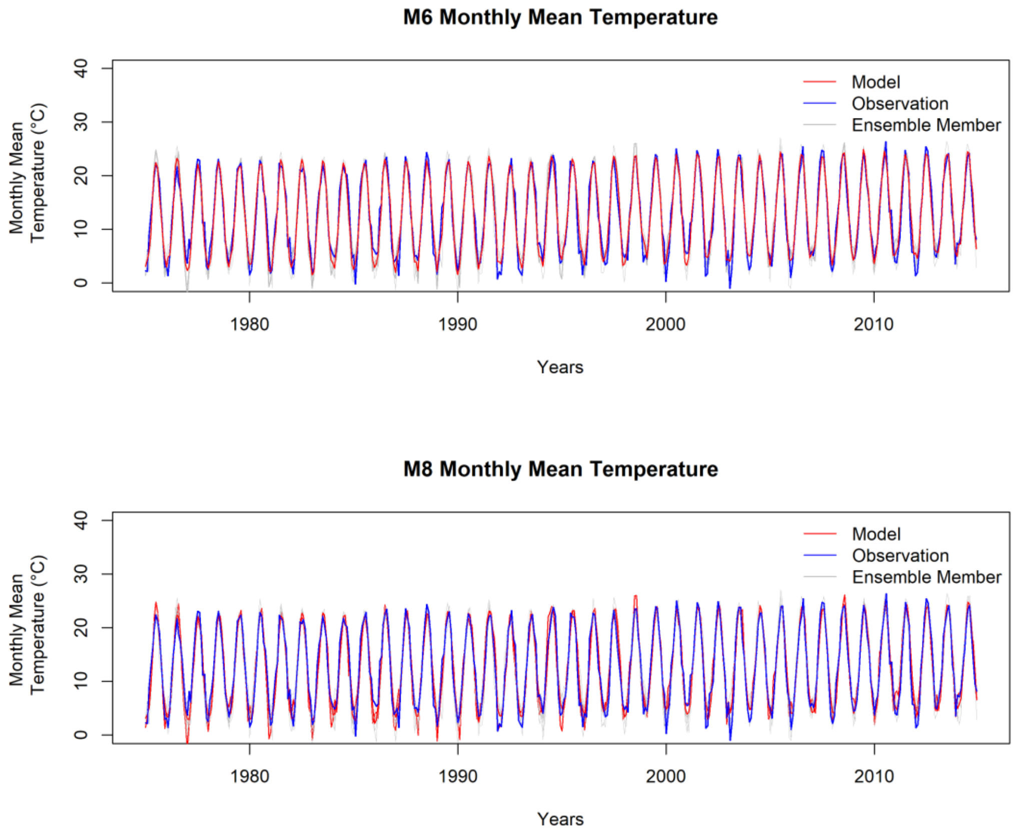


Figure 3.36 G12 subbasin monthly mean temperature for M6 and M8 model scenario

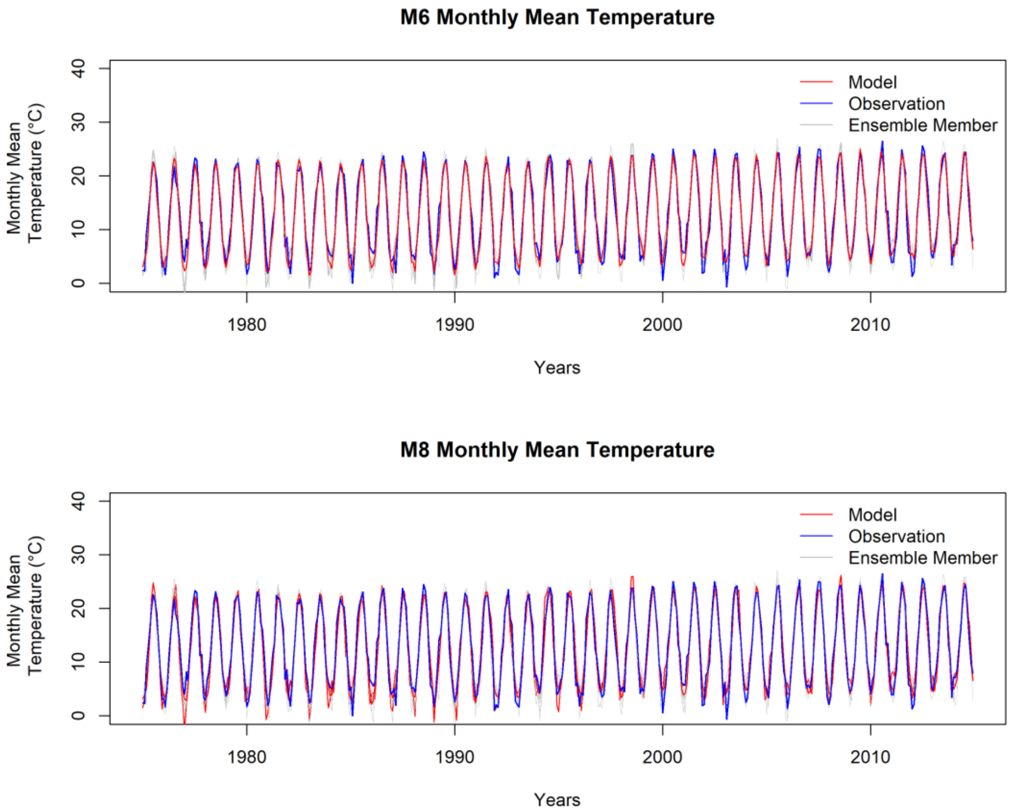
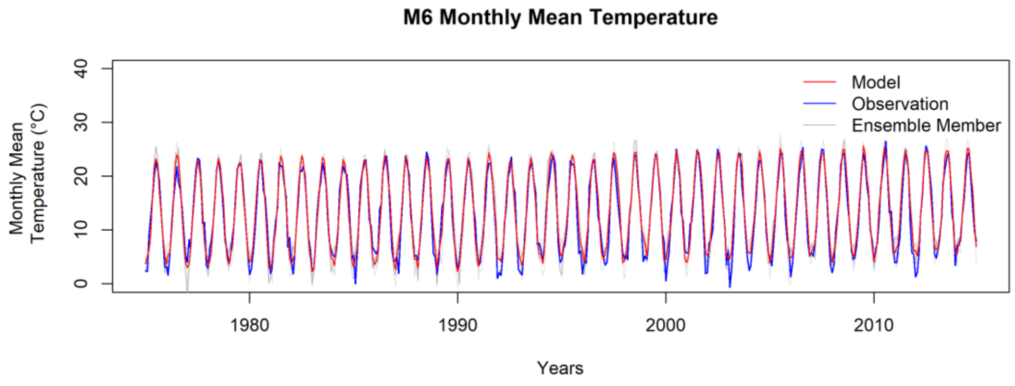


Figure 3.37 G18 subbasin monthly mean temperature for M6 and M8 model scenario



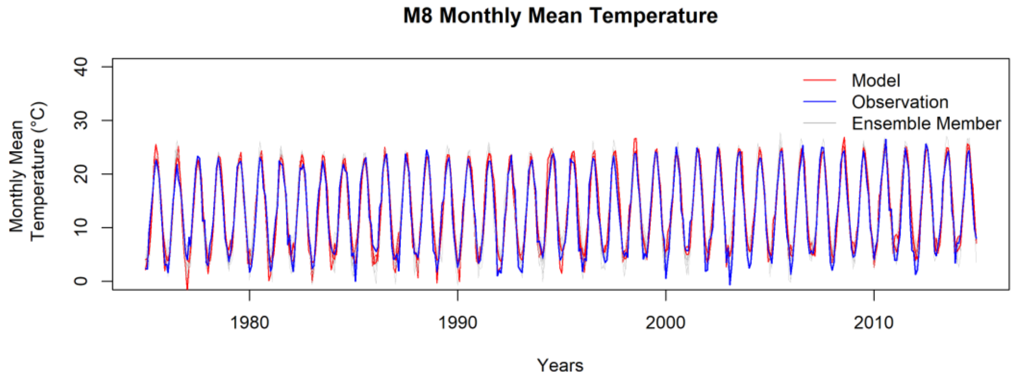
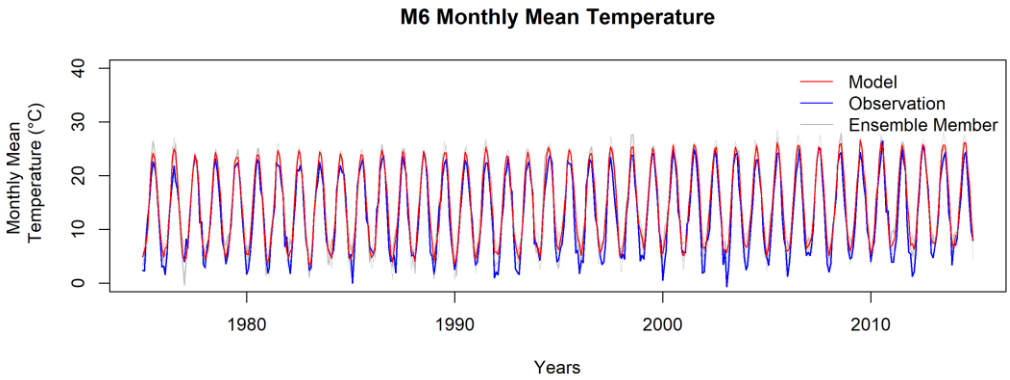


Figure 3.38 N14 subbasin monthly mean temperature for M6 and M8 model scenario



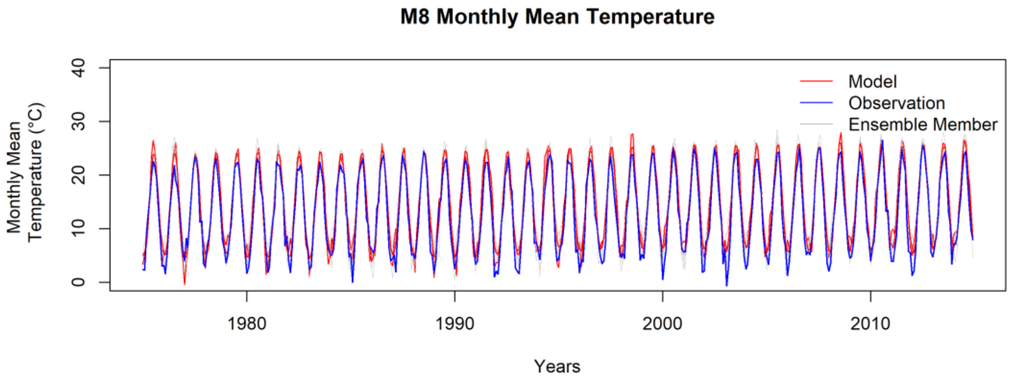


Figure 3.39 N15 subbasin monthly mean temperature for M6 and M8 model scenario

From Figure 3.40 to Figure 3.44, interquartile range of the M8 model ensemble for annual mean temperature is presented along with the ERA5 observations for each subbasin.

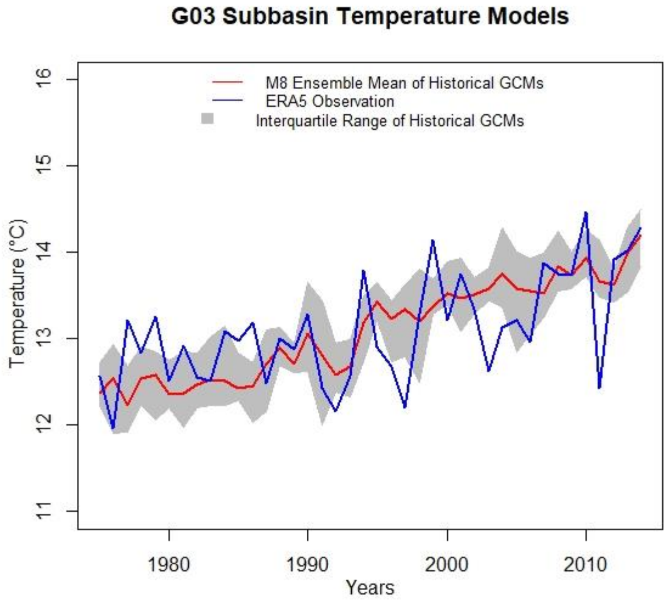


Figure 3.40 G03 subbasin annual historical temperature values with ERA5 observations and GCM data

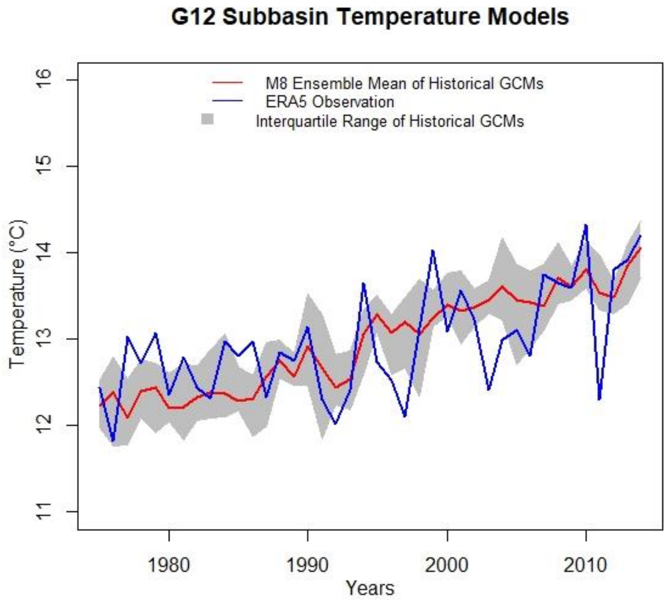


Figure 3.41 G12 subbasin annual historical temperature values with ERA5 observations and GCM data

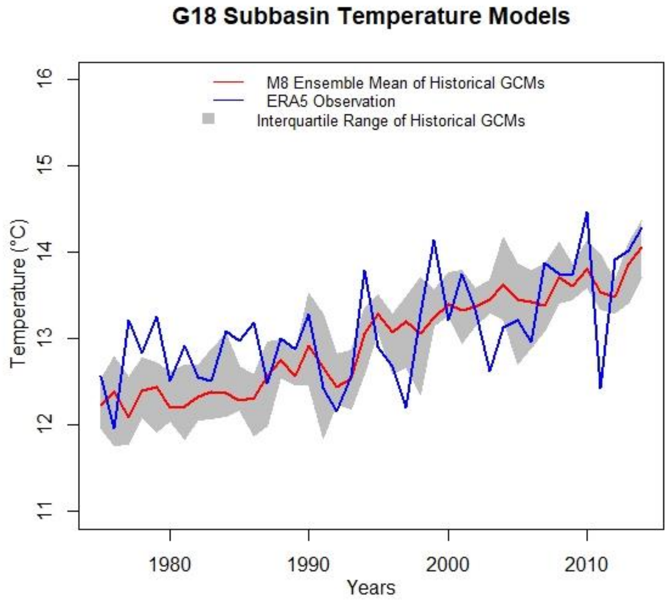


Figure 3.42 G18 subbasin annual historical temperature values with ERA5 observations and GCM data

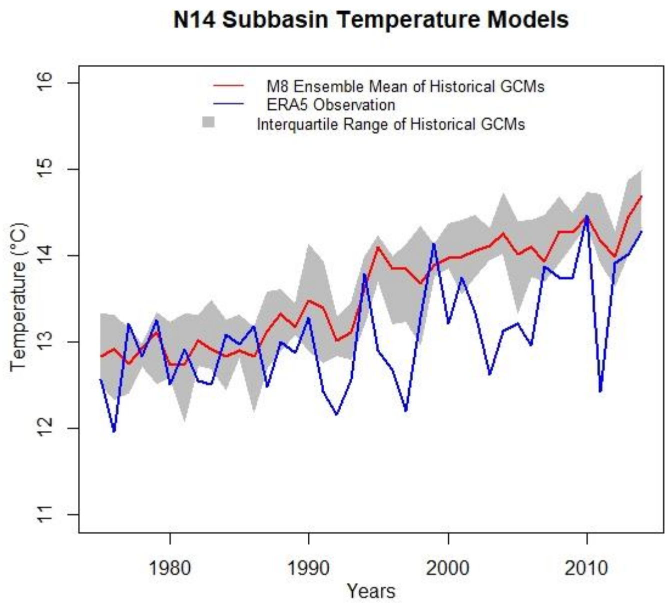


Figure 3.43 N14 subbasin annual historical temperature values with ERA5 observations and GCM data

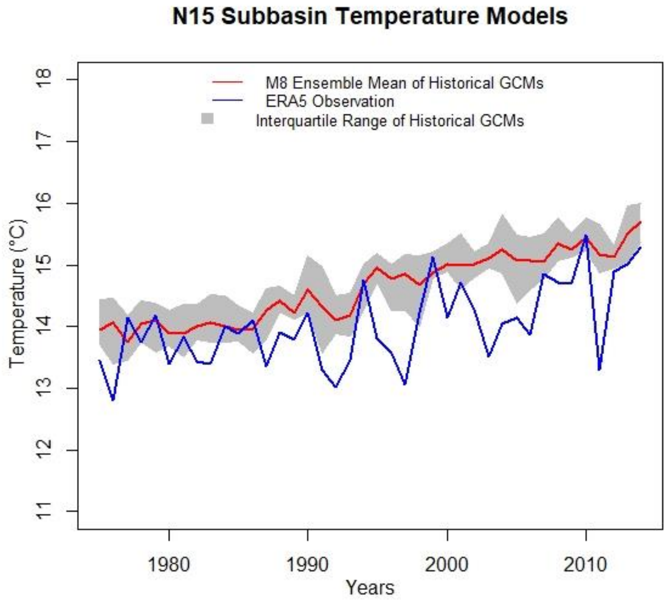


Figure 3.44 N15 subbasin annual historical temperature values with ERA5 observations and GCM data

3.3.2 Future Period

Monthly, seasonal and annual anomalies in each subbasin with respect to historical period are presented in Table 3.12 - Table 3.16. From Figure 3.45 to Figure 3.49 M6 and M8 model ensemble time series plots for annual mean temperature for both SSP2-4.5 and SSP5-8.5 scenario of each subbasin is presented.

Each subbasin is getting warmer with both SSP2-4.5 and SSP5-8.5 scenarios. Especially in summer deviation is at a higher level than in other periods in comparison to the historical period. Increase in temperatures are more pronounced with SSP5-8.5 scenario as expected. The difference between SSP2-4.5 and SSP5-8.5 scenarios was revealed especially in far future periods.

G03 subbasin

Table 3.12 Monthly, seasonal and annual temperature changes in G03 subbasin with respect to historical period for M6 and M8 scenarios

	M6 SSP2-4.5			M6 SSP5-8.5			M8 SSP2-4.5			M8 SSP5-8.5		
	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)
Spring	1.53	2.29	2.78	1.33	2.91	5.01	1.12	1.99	2.49	1.05	2.80	4.78
Summer	2.08	3.13	3.81	2.49	4.54	7.50	1.81	2.86	3.59	2.14	4.15	6.83
Fall	2.03	2.94	3.44	1.78	3.72	5.89	1.43	2.32	2.92	1.46	3.22	5.32
Winter	1.32	2.28	2.93	1.02	2.52	4.02	1.10	1.90	2.49	1.03	2.54	4.31
Annual	1.74	2.66	3.24	1.65	3.42	5.61	1.37	2.26	2.87	1.42	3.18	5.31

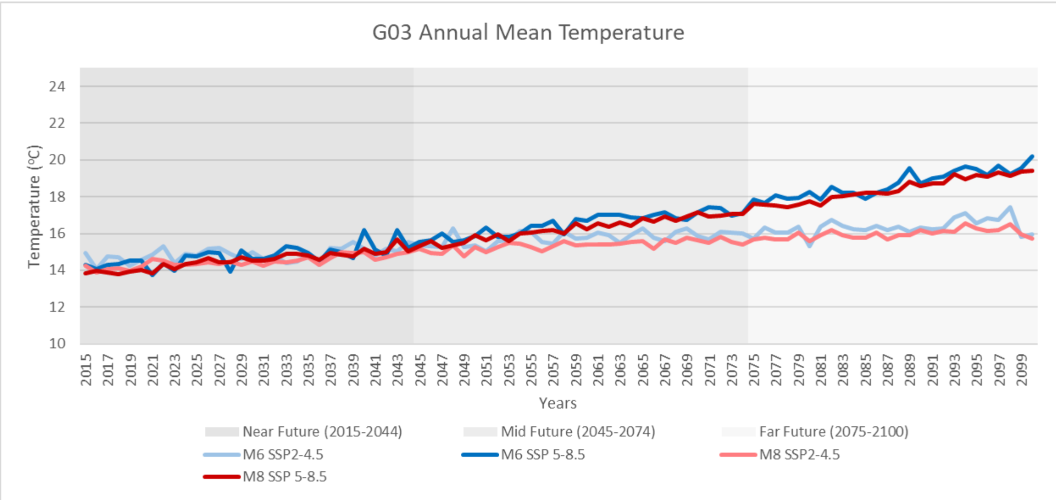


Figure 3.45 G03 subbasin annual mean temperature in SSP2-4.5 and SSP5-8.5 scenarios

G12 subbasin

Table 3.13 Monthly, seasonal and annual temperature changes in G12 subbasin with respect to historical period for M6 and M8 scenarios

	M6 SSP2-4.5			M6 SSP5-8.5			M8 SSP2-4.5			M8 SSP5-8.5		
	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)
Spring	1.53	2.29	2.78	1.33	2.91	5.01	1.12	1.99	2.50	1.05	2.80	4.78
Summer	2.07	3.13	3.81	2.49	4.53	7.52	1.80	2.85	3.59	2.13	4.12	6.83
Fall	2.04	2.93	3.43	1.79	3.72	5.88	1.43	2.31	2.91	1.46	3.20	5.29
Winter	1.30	2.28	2.95	0.99	2.52	4.05	1.09	1.90	2.50	1.01	2.55	4.34
Annual	1.74	2.66	3.24	1.65	3.42	5.61	1.36	2.26	2.88	1.41	3.17	5.31

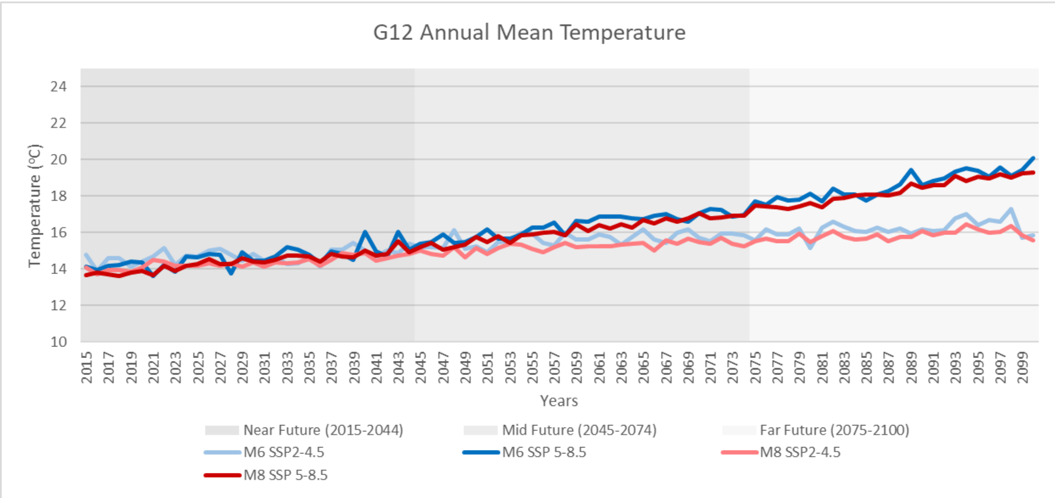


Figure 3.46 G12 subbasin annual mean temperature in SSP2-4.5 and SSP5-8.5 scenarios

G18 subbasin

Table 3.14 Monthly, seasonal and annual temperature changes in G18 subbasin with respect to historical period for M6 and M8 scenarios

	M6 SSP2-4.5			M6 SSP5-8.5			M8 SSP2-4.5			M8 SSP5-8.5		
	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)
Spring	1.53	2.29	2.78	1.34	2.91	5.00	1.55	2.27	2.72	1.34	2.87	4.93
Summer	2.07	3.13	3.81	2.48	4.53	7.52	2.01	3.12	3.84	2.30	4.52	7.63
Fall	2.04	2.93	3.43	1.79	3.72	5.88	2.03	2.91	3.40	1.76	3.70	5.89
Winter	1.30	2.28	2.95	0.99	2.52	4.05	1.27	2.24	2.88	0.86	2.41	3.92
Annual	1.73	2.66	3.24	1.65	3.42	5.61	1.72	2.63	3.21	1.57	3.37	5.59

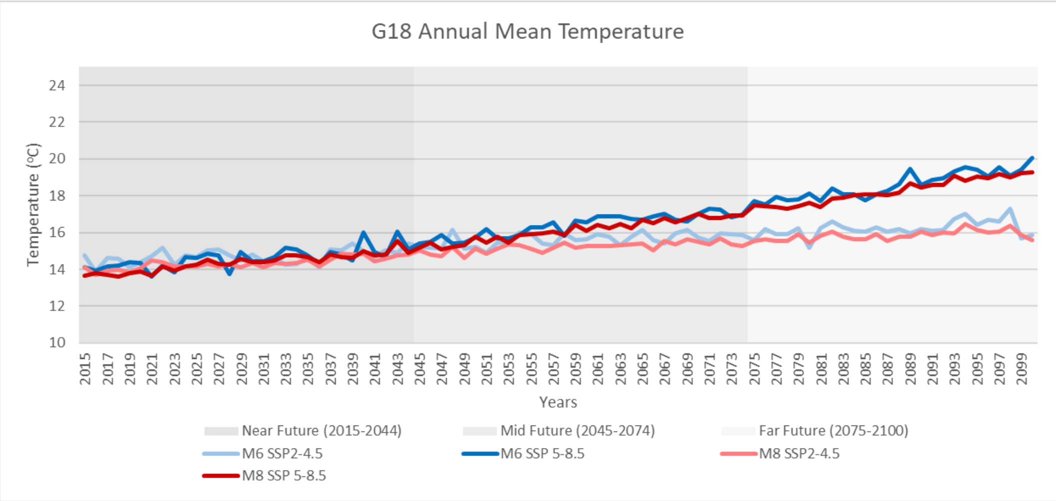


Figure 3.47 G18 subbasin annual mean temperature in SSP2-4.5 and SSP5-8.5 scenarios

N14 subbasin

Table 3.15 Monthly, seasonal and annual temperature changes in N14 subbasin with respect to historical period for M6 and M8 scenarios

	M6 SSP2-4.5			M6 SSP5-8.5			M8 SSP2-4.5			M8 SSP5-8.5		
	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)
Spring	1.53	2.28	2.77	1.33	2.91	5.02	1.14	1.99	2.55	0.98	2.83	4.82
Summer	2.07	3.13	3.82	2.46	4.54	7.52	1.80	2.82	3.61	2.03	4.07	6.71
Fall	2.03	2.94	3.44	1.77	3.73	5.92	1.39	2.26	2.87	1.35	3.19	5.24
Winter	1.33	2.28	2.93	1.04	2.53	4.02	1.05	1.84	2.48	0.87	2.47	4.21
Annual	1.74	2.66	3.24	1.65	3.43	5.62	1.34	2.23	2.88	1.31	3.14	5.24

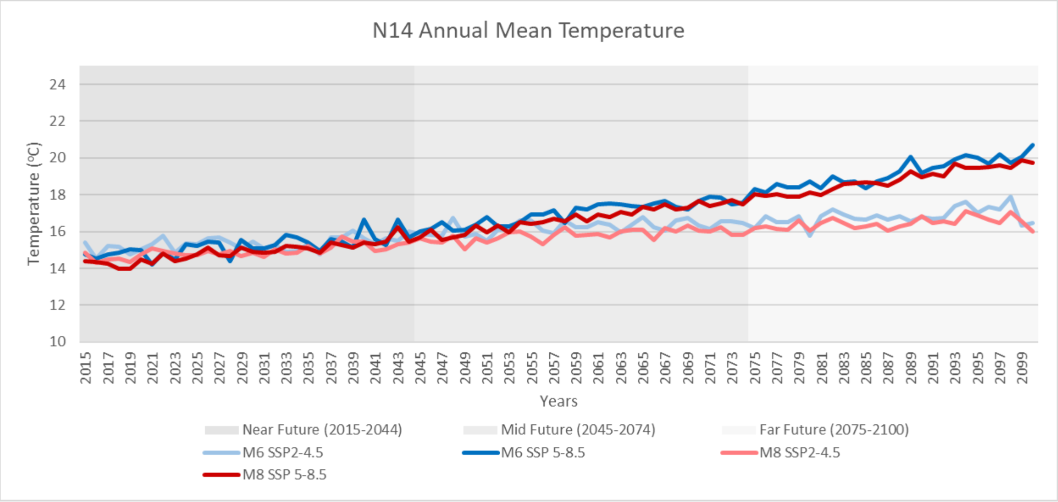


Figure 3.48 N14 subbasin annual mean temperature in SSP2-4.5 and SSP5-8.5 scenarios

N15 subbasin

Table 3.16 Monthly, seasonal and annual temperature changes in N15 subbasin with respect to historical period for M6 and M8 scenarios

	M6 SSP2-4.5			M6 SSP5-8.5			M8 SSP2-4.5			M8 SSP5-8.5		
	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)	Near Future (ºC)	Mid Future (ºC)	Far Future (ºC)
Spring	1.56	2.30	2.81	1.36	2.95	5.05	1.14	1.99	2.50	1.07	2.81	4.79
Summer	2.06	3.12	3.81	2.46	4.52	7.46	1.83	2.87	3.59	2.18	4.18	6.85
Fall	2.02	2.93	3.43	1.78	3.72	5.89	1.45	2.34	2.94	1.49	3.26	5.36
Winter	1.31	2.26	2.92	1.02	2.51	4.00	1.09	1.88	2.46	1.02	2.52	4.27
Annual	1.74	2.65	3.24	1.65	3.42	5.60	1.38	2.27	2.87	1.44	3.19	5.32

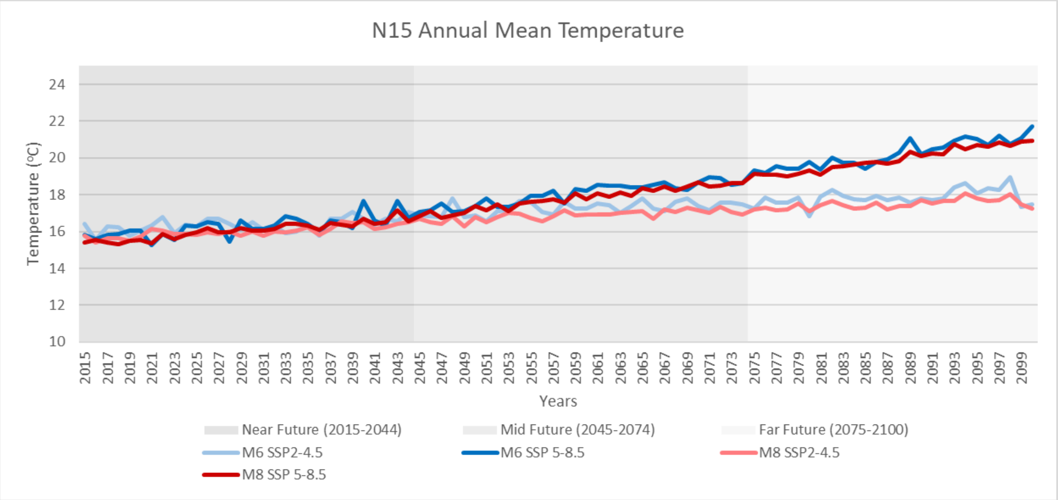


Figure 3.49 N15 subbasin annual mean temperature in SSP2-4.5 and SSP5-8.5 scenarios

Changes in each subbasin can be visualized in Figure 3.50 and Figure 3.51 for M8 model ensemble SSP2-4.5 and SSP5-8.5 scenarios respectively.

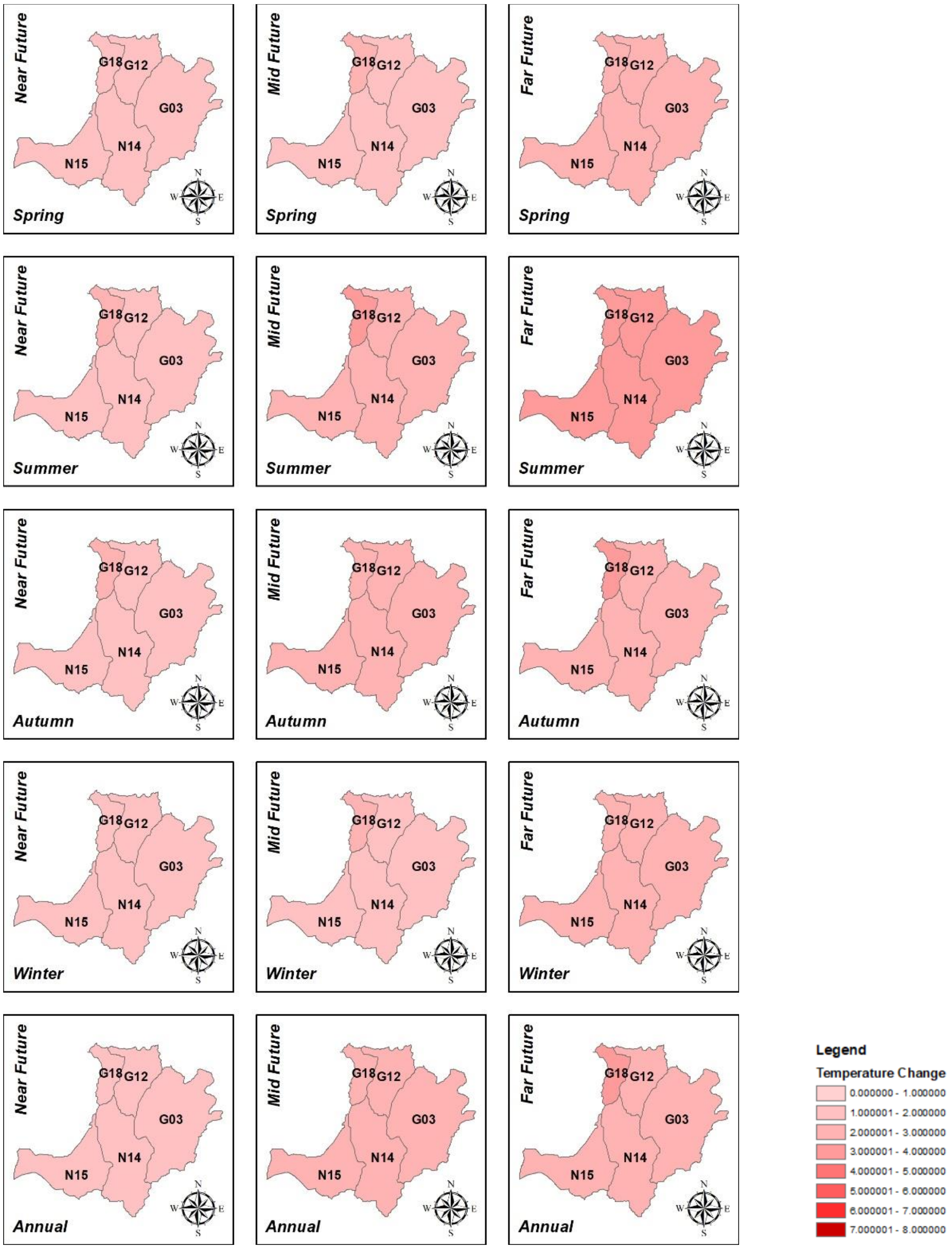


Figure 3.50 Seasonal temperature changes with respect to historical period in each subbasin – SSP2-4.5 scenario

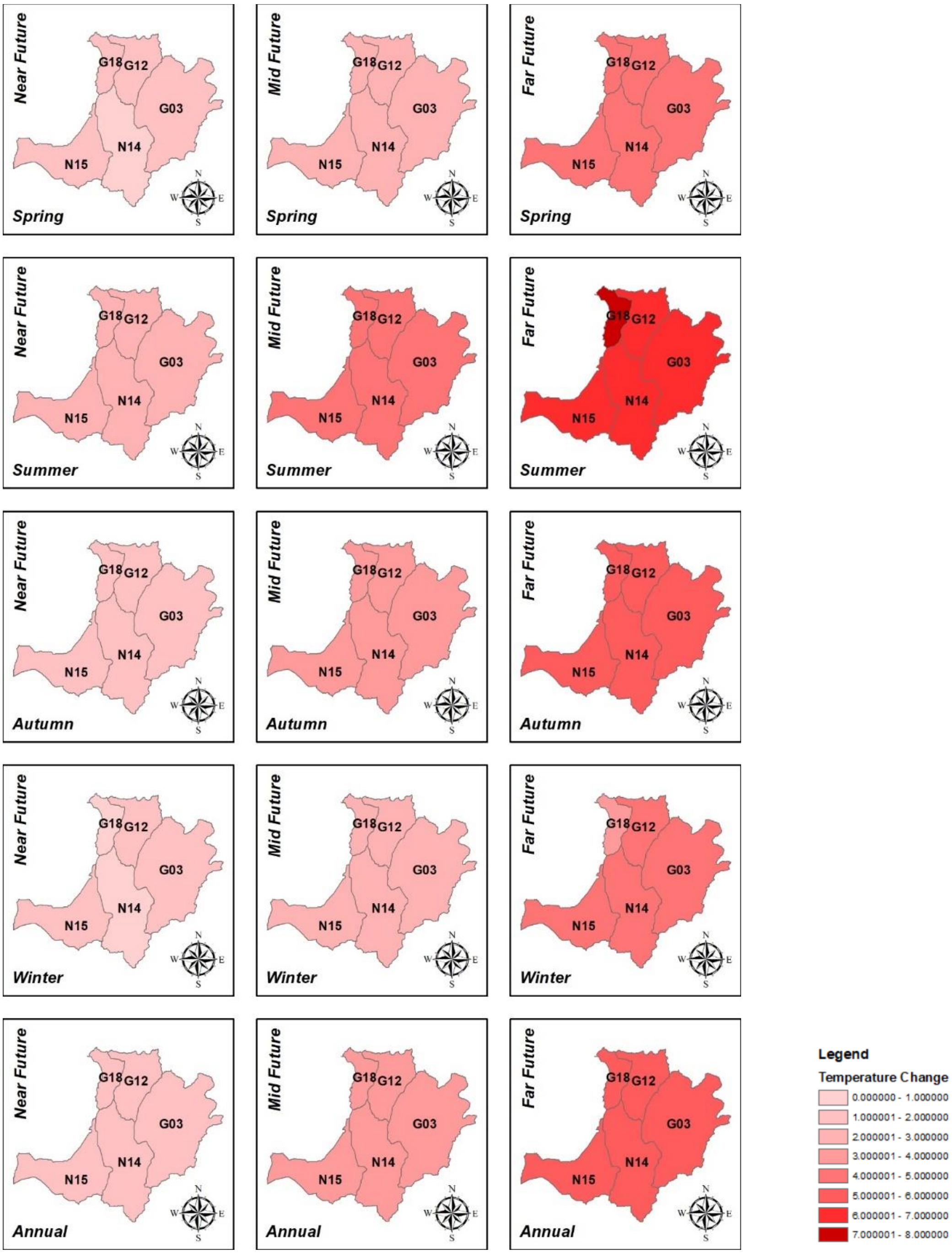


Figure 3.51 Seasonal temperature changes with respect to historical period in each subbasin – SSP5-8.5 scenario

3.3.3 Trend Analysis

Trend in temperature data is calculated for historical period and three future periods for each scenario (SSP2-4.5 and SSP5-8.5).

There is a statistically significant increasing trend within all subbasins at a 1% significance level in the historical period. Within SSP2-45 scenario, summer temperature values show statistically significant increasing trend at 1% significance level in all subbasins. In Spring and Autumn seasons, trend in each subbasin becomes significant at a lower significance level as we move from near future to far future period becoming insignificant in the far future period. Temperature values of all subbasins are significantly increasing in SSP5-8.5 scenario in all seasons with 1% significance level.

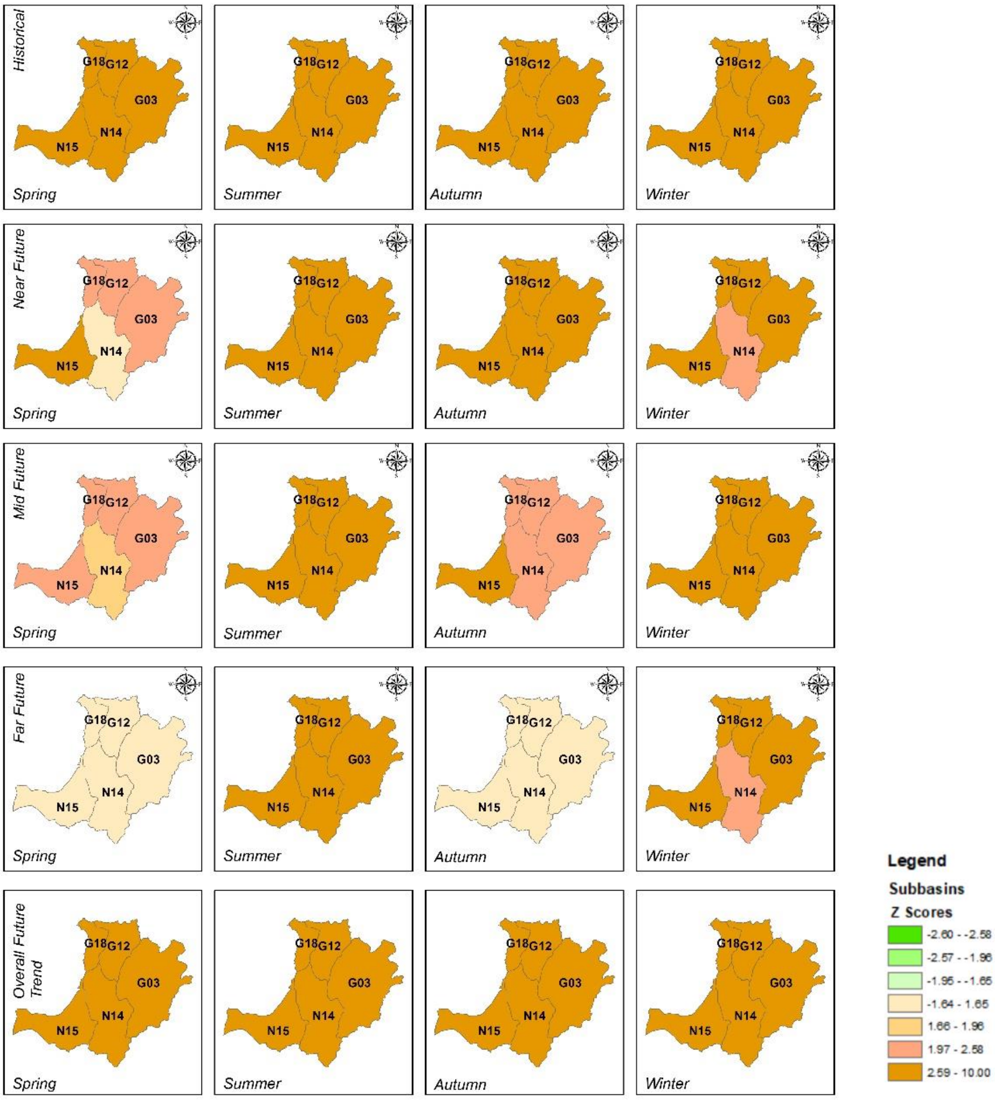


Figure 3.52 Seasonal temperature trends in subbasins for SSP2-4.5 Scenario

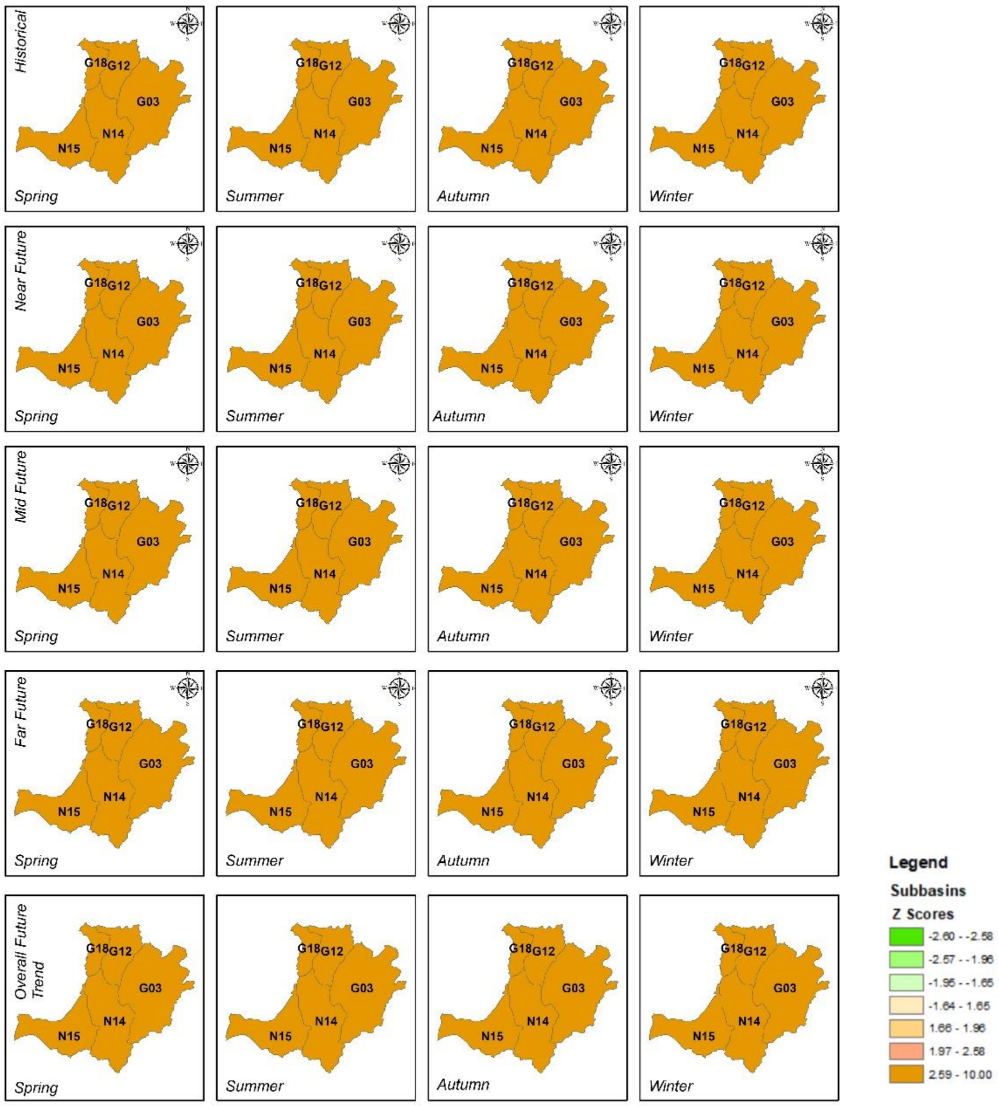


Figure 3.53 Seasonal temperature trends in subbasins for SSP5-8.5 Scenario

3.4 Evaluation of GR2M Discharge

3.4.1 Historical Period

ERA5 observations are employed in calibrated GR2M model. The comparison between annual total discharge resulting from calibration and ERA5 data is given for calibrated subbasins (G03, G12,N14) in Figure 3.54, Figure 3.55 and Figure 3.56.

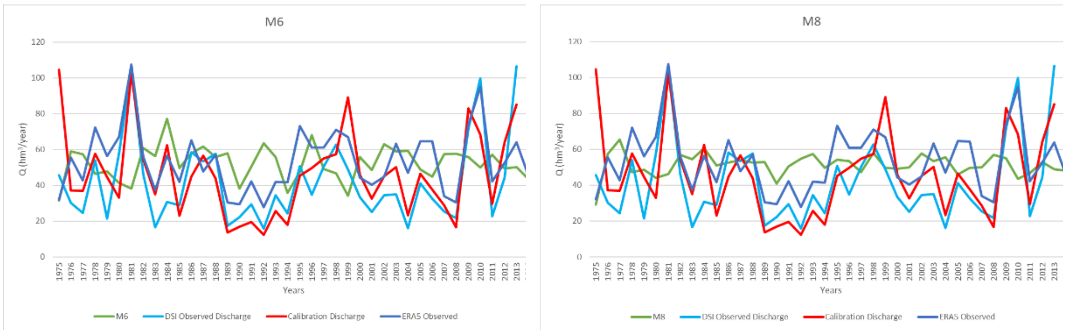


Figure 3.54 G03 subbasin historical period discharge

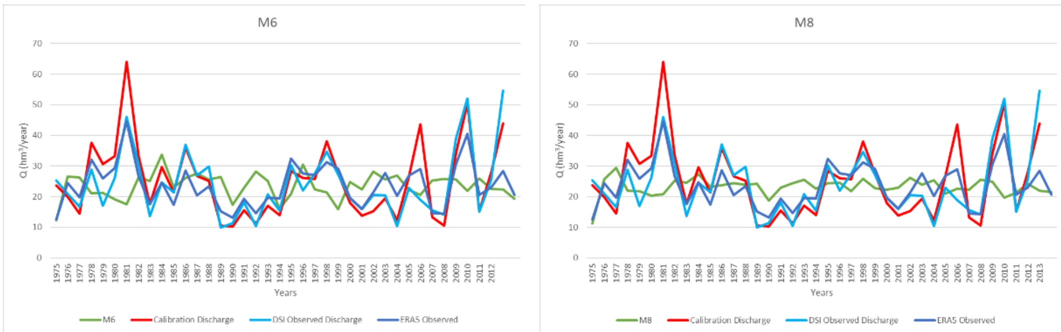


Figure 3.55 G12 subbasin historical period discharge

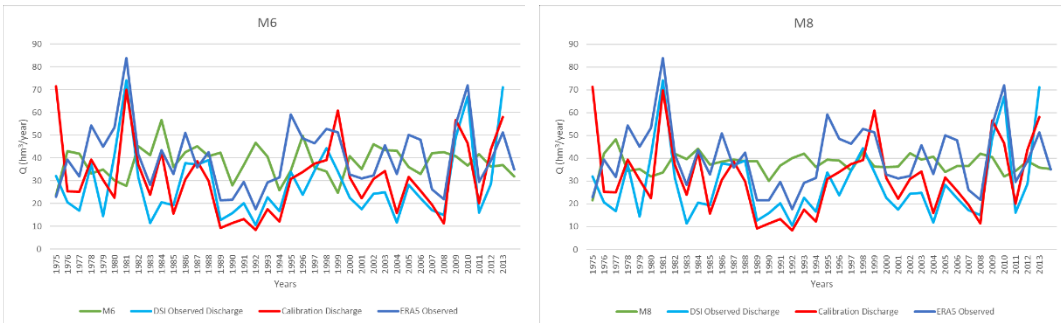


Figure 3.56 N14 subbasin historical period discharge

Discharge in each subbasin is calculated with corresponding model parameters of GR2M model calibration. Individual model and ensemble inputs are employed in GR2M model.

Table 3.17 Correlation Coefficient (r) and RMSE values of discharge output from each model scenario

	G03		G12		G18		N14		N15	
	r	**RMSE**	**r**	**RMSE**	**r**	**RMSE**	**r**	**RMSE**	**r**	**RMSE**
M1	0.55	4.94	0.57	1.91	0.57	1.03	0.53	3.84	0.53	3.59
M2	0.54	5.16	0.55	2	0.54	1.08	0.51	4.02	0.49	3.83
M3	0.57	5.03	0.59	1.94	0.58	1.05	0.54	3.91	0.52	3.67
M4	0.56	5.01	0.57	1.94	0.57	1.04	0.54	3.86	0.53	3.59
M5	0.56	4.81	0.59	1.82	0.58	0.99	0.54	3.76	0.52	3.55
M6	0.67	4.05	0.69	1.54	0.68	0.84	0.65	3.22	0.63	3.08
M6_2*	0.67	4.07	0.66	5.07	0.66	5.91	0.66	4.22	0.71	4.33
M7	0.69	3.96	0.7	1.51	0.7	0.82	0.67	3.15	0.65	3.01
M8	0.71	3.81	0.73	1.43	0.72	0.78	0.69	3.06	0.67	2.94
M9	0.72	3.74	0.74	1.41	0.73	0.77	0.7	3.00	0.69	2.88

*M6_2 model input is calculated with the mean of M1, M2, M3 and M5 discharge outputs

In M6 and M8 model ensembles, it is seen that RMSE values are lower and r values are higher than individual model inputs (M1-M5). In this section M6_2 discharge is calculated from mean of discharge outputs of individual models employed in M6 ensemble. It is seen that RMSE values get higher when mean of the discharge is taken.

In Figure 3.57 through Figure 3.61, it can be seen that M6 and M8 model ensembles, peak monthly discharge in each subbasin is represented however, both model ensembles are underestimating the higher discharge values.

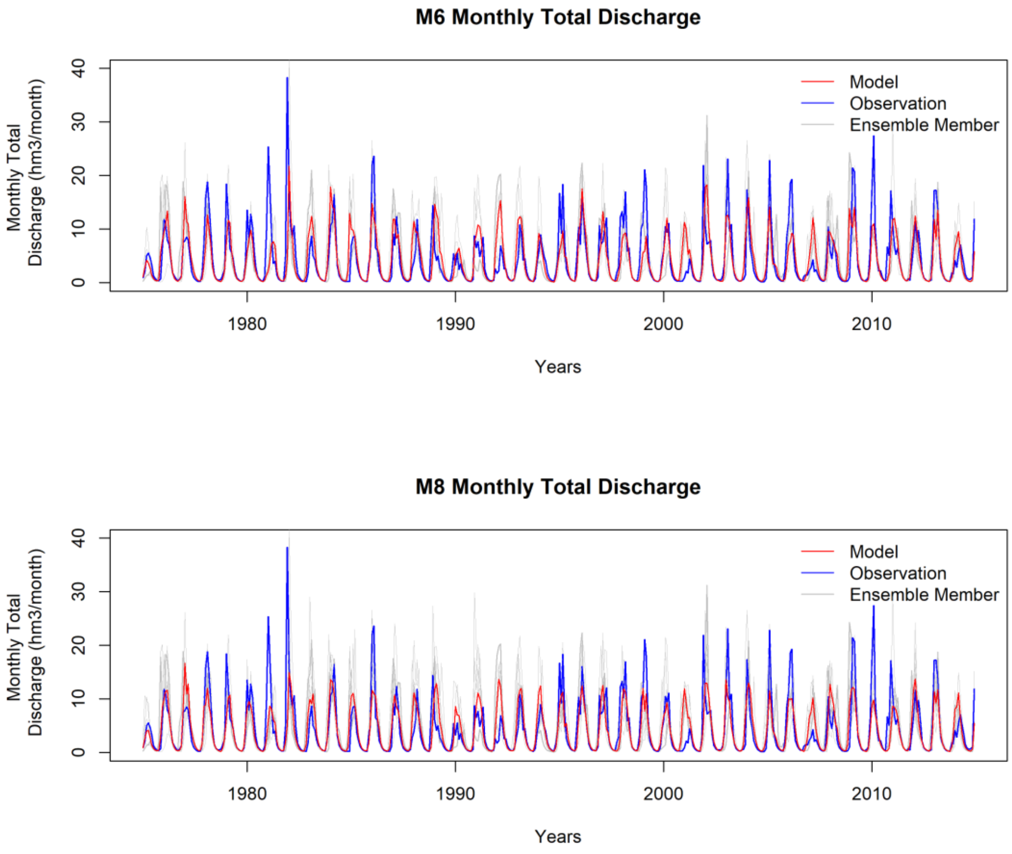
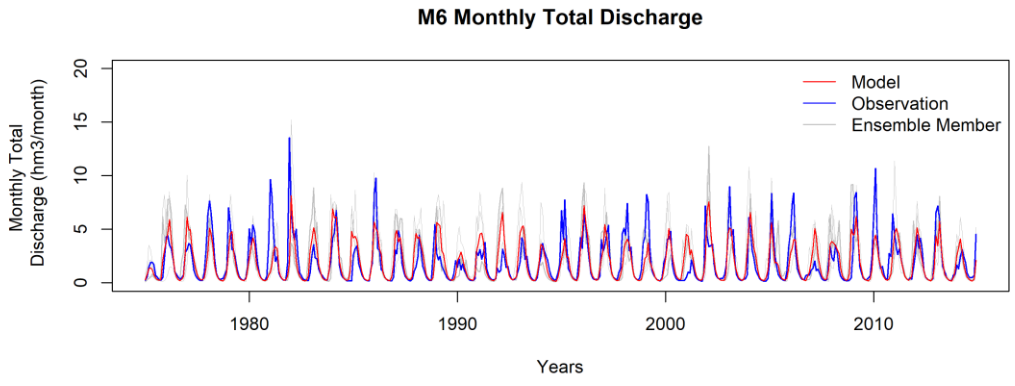


Figure 3.57 G03 subbasin monthly total discharge for M6 and M8 model scenario



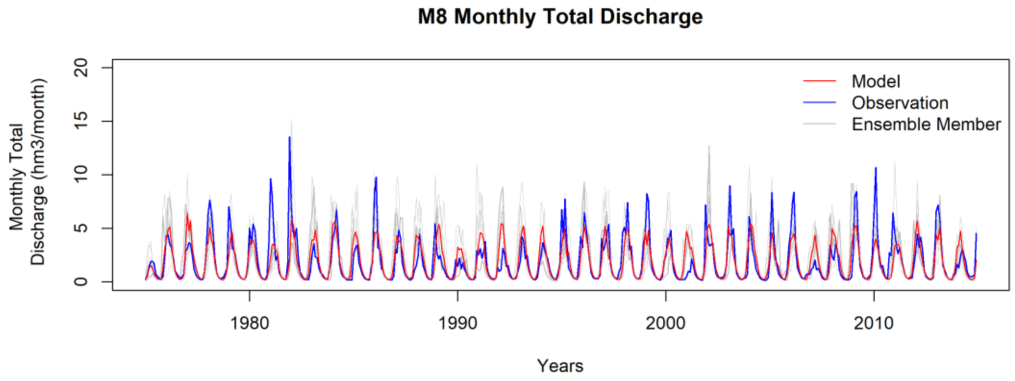


Figure 3.58 G12 subbasin monthly total discharge for M6 and M8 model scenario

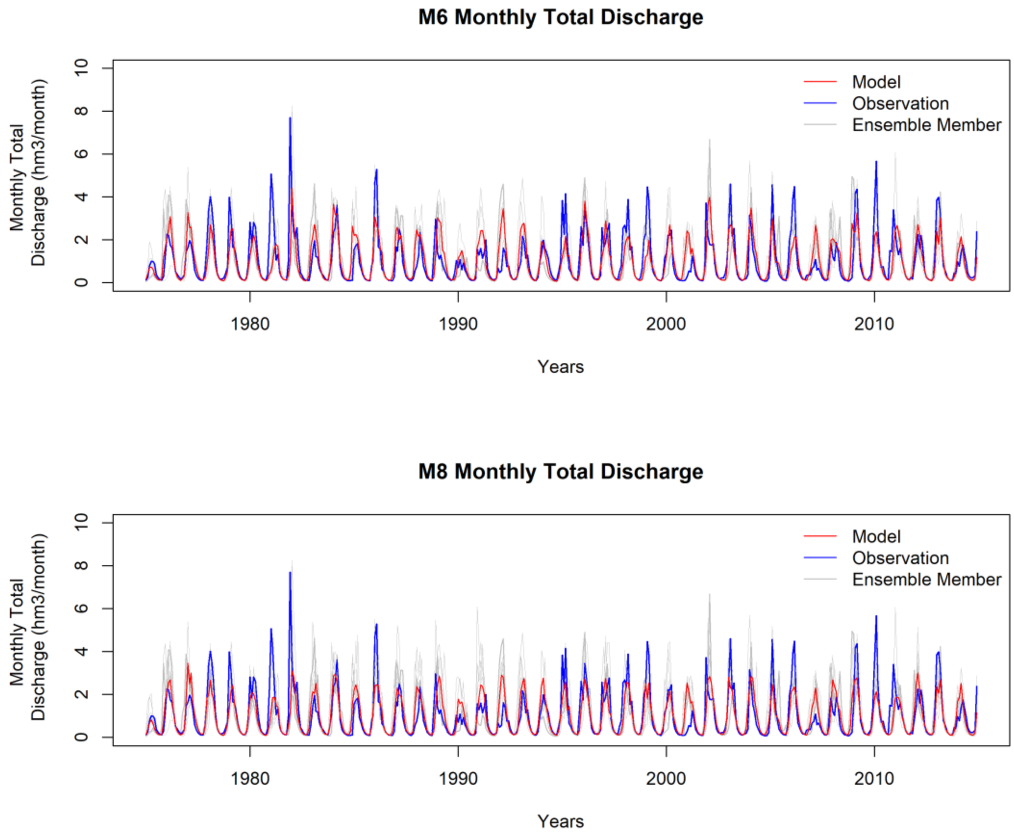


Figure 3.59 G18 subbasin monthly total discharge for M6 and M8 model scenario

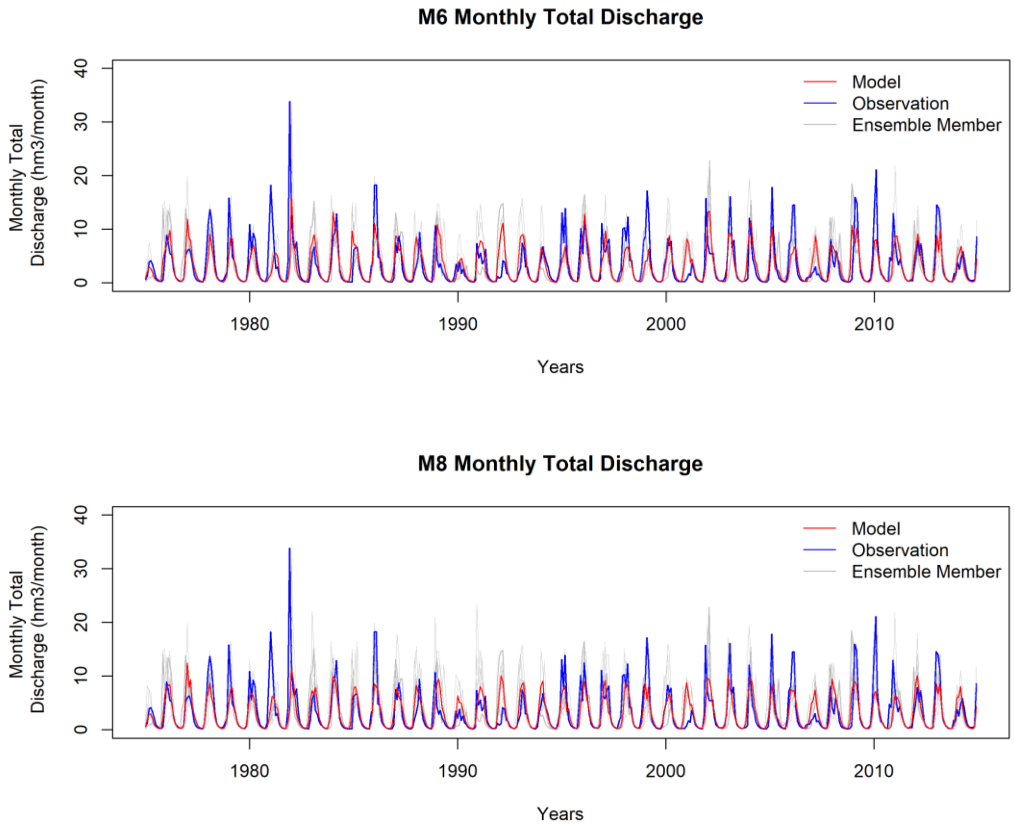


Figure 3.60 N14 subbasin monthly total discharge for M6 and M8 model scenario

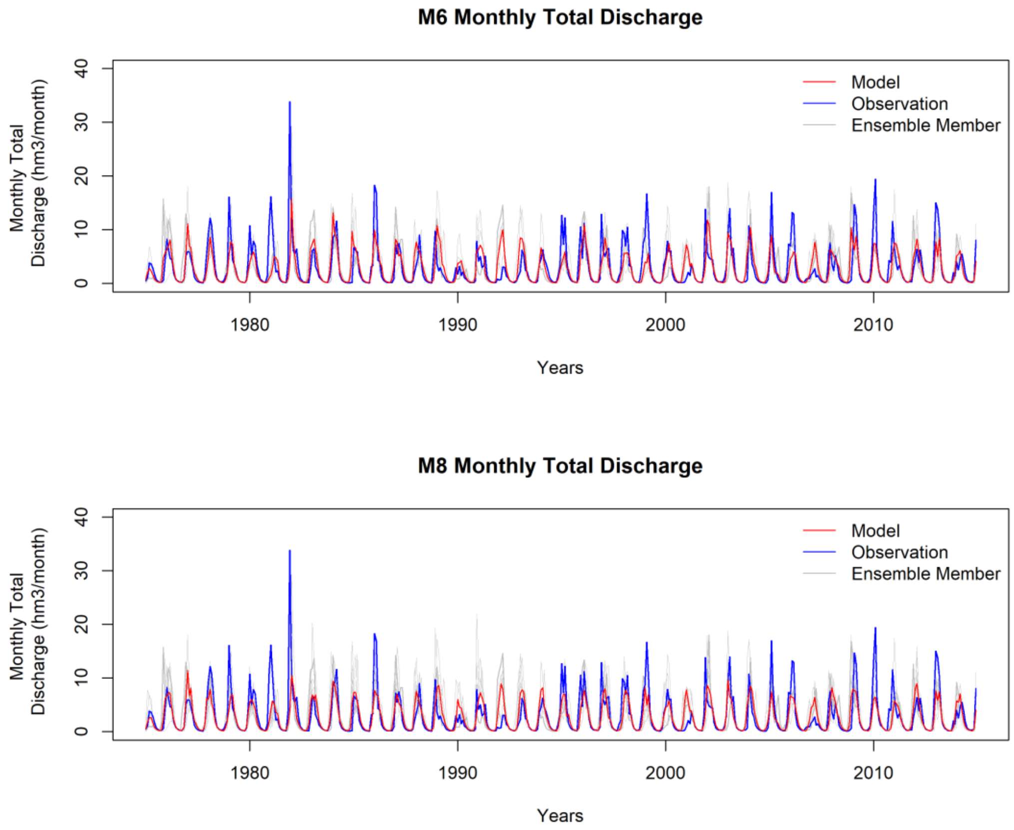


Figure 3.61 N15 subbasin monthly total discharge for M6 and M8 model scenario

From Figure 3.62 to Figure 3.66, interquartile range of the M8 model ensemble for annual total discharge is presented along with the ERA5 observations for each subbasin.

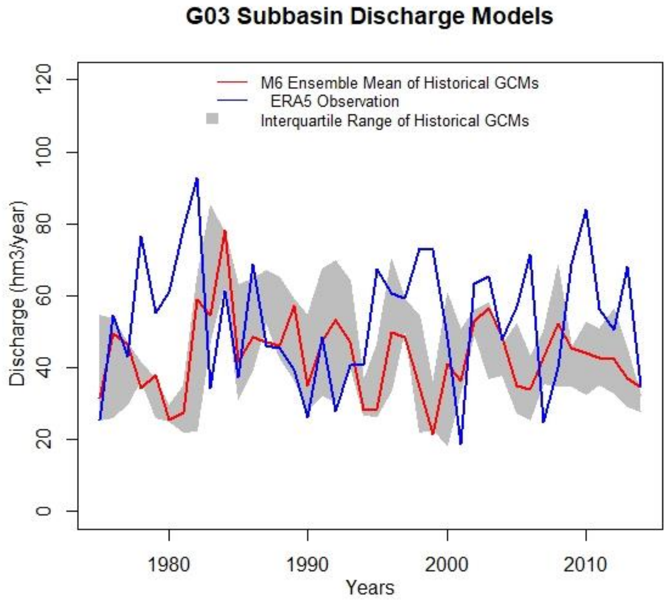


Figure 3.62 G03 subbasin annual historical discharge values with ERA5 observations and GCM data

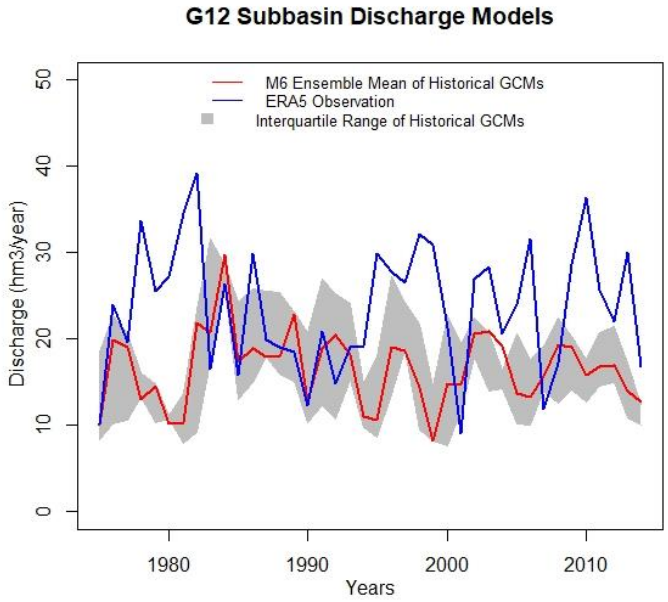


Figure 3.63 G12 subbasin annual historical discharge values with ERA5 observations and GCM data

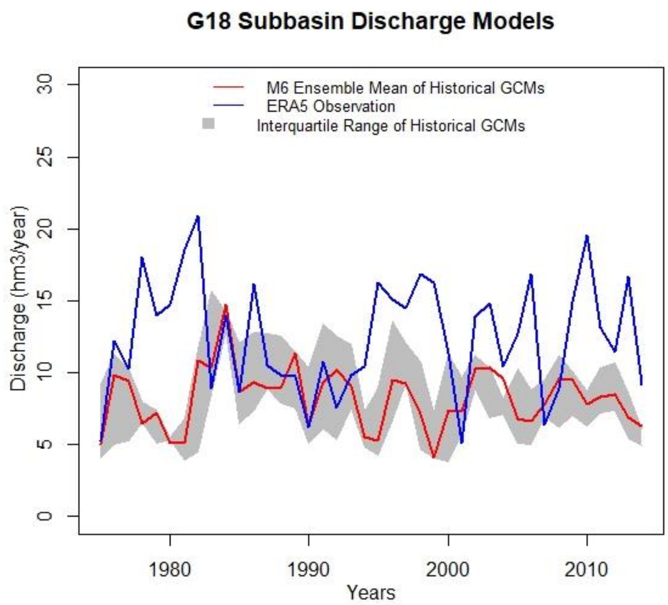


Figure 3.64 G18 subbasin annual historical discharge values with ERA5 observations and GCM data

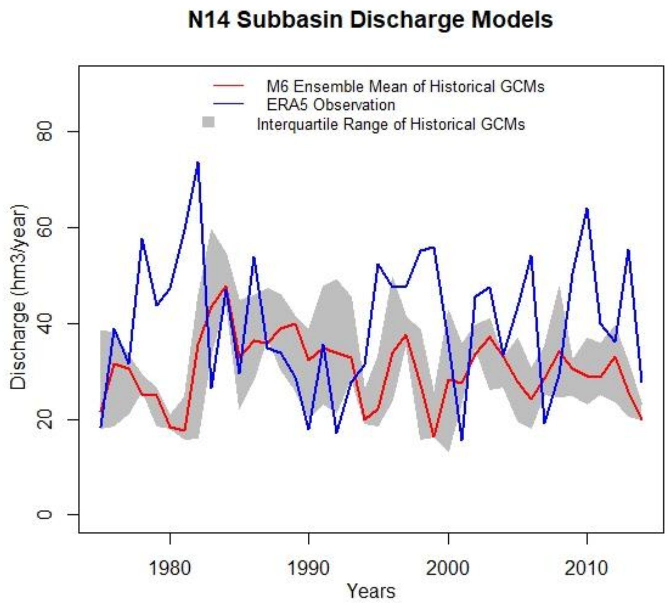


Figure 3.65 N14 subbasin annual historical discharge values with ERA5 observations and GCM data

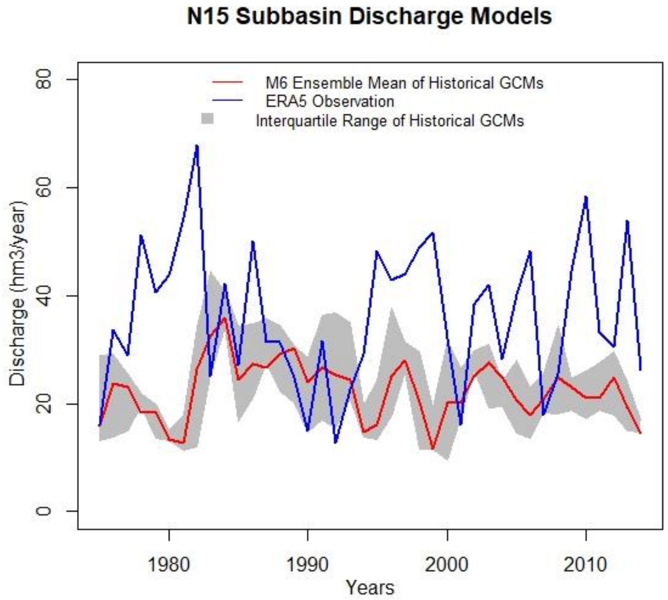


Figure 3.66 N15 subbasin annual historical discharge values with ERA5 observations and GCM data

3.4.2 Future Period

For each model subbasin, seasonal and annual total discharge are compared with the historical period. Seasonal and annual means are given with the percentage changes for each subbasin in Table 3.18 - Table 3.22. Also, the annual total discharge within each subbasin is given from Figure 3.67 to Figure 3.71.

In all subbasins in M6 and M8 ensemble mean results and both scenarios show a decrease in seasonal and annual total discharges. The amount decrease is higher with the SSP5-8.5 scenario as expected.

<u>*G03 subbasin*</u>

Table 3.18 Seasonal and annual changes in G03 subbasin discharge with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	**Near Future (hm^3)**	**Mid Future (hm^3)**	**Far Future (hm^3)**	**Near Future (hm^3)**	**Mid Future (hm^3)**	**Far Future (hm^3)**	**H**	**Near Future (hm^3)**	**Mid Future (hm^3)**	**Far Future (hm^3)**	**Near Future (hm^3)**	**Mid Future (hm^3)**	**Far Future (hm^3)**
Spring	20.6	19.7	18.5	19.5	19.4	18.4	14.0	19.9	18.9	17.8	17.6	19.1	16.8	13.8
	%	-4.4	-10.49	-5.54	-5.85	-11.03	-32.03	%	-4.94	-10.79	-11.61	-4.21	-15.38	-30.59
Summer	3.4	3.1	2.9	3.0	3.3	2.6	2.1	3.5	3.3	3.0	2.9	3.3	2.7	2.2
	%	-9.56	-14.8	-13.71	-5.08	-25.13	-39.26	%	-6.25	-14.67	-15.92	-6.19	-22.05	-38.05
Autumn	2.1	2.0	1.8	2.0	1.7	1.3	1.1	2.0	1.7	1.6	1.6	1.7	1.2	0.9
	%	-3.05	-11.61	-1.94	-16.33	-38.02	-47.43	%	-12.98	-19.99	-19.81	-15.05	-38.98	-52.63
Winter	26.0	26.4	25.1	25.4	24.5	21.5	16.3	26.0	24.6	23.0	22.4	24.1	18.8	15.2
	%	1.23	-3.49	-2.53	-5.8	-17.46	-37.52	%	-5.36	-11.49	-13.87	-7.2	-27.56	-41.32
Annual	52.2	51.2	48.4	49.9	49.0	43.7	33.5	51.3	48.5	45.3	44.5	48.1	39.6	32.1
	%	-1.88	-7.32	-4.43	-6.19	-16.24	-35.86	%	-5.55	-11.76	-13.36	-6.27	-22.9	-37.36

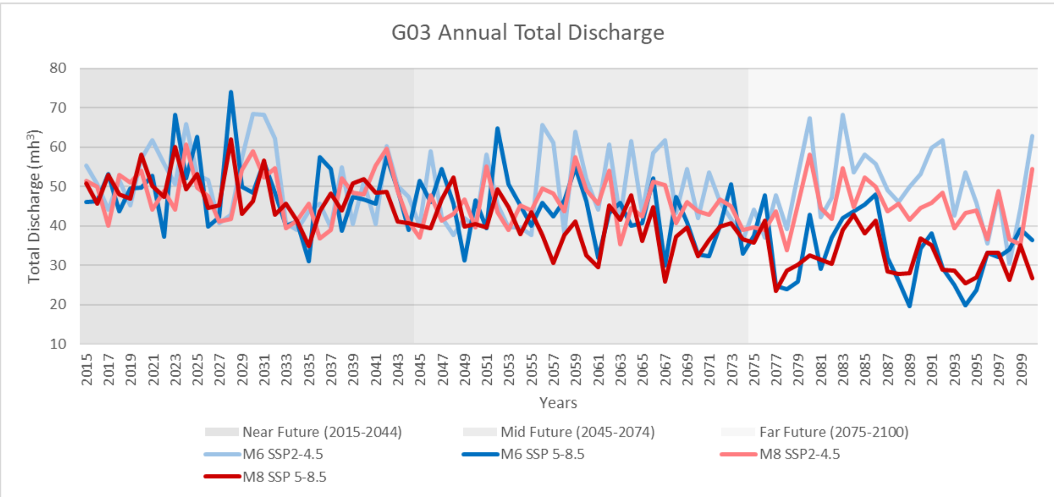


Figure 3.67 G03 subbasin annual total discharge in SSP2-4.5 and SSP5-8.5 scenarios

G12 subbasin

Table 3.19 Seasonal and annual changes in G12 subbasin discharge with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)
Spring	9.7	9.3	8.7	9.1	9.1	8.4	6.4	9.4	8.9	8.4	8.3	9.0	7.8	6.3
	%	-4.45	-10.09	-6.06	-6.21	-13.03	-34	%	-5.37	-11.11	-12.27	-4.8	-17.41	-32.98
Summer	2.0	1.9	1.8	1.8	1.9	1.6	1.3	2.1	2.0	1.8	1.8	2.0	1.6	1.3
	%	-9.04	-14.35	-13.62	-6.18	-24.33	-37.89	%	-6.03	-14.28	-15.86	-7.08	-22	-36.93
Autumn	1.2	1.1	1.0	1.1	1.0	0.8	0.7	1.2	1.0	0.9	0.9	1.0	0.8	0.6
	%	-8.15	-16.53	-11.13	-16.06	-35.53	-45.97	%	-13.23	-20.65	-22.12	-14.83	-35.94	-48.56
Winter	10.5	10.4	9.8	9.9	9.6	8.1	6.0	10.5	9.7	9.0	8.7	9.5	7.2	5.7
	%	-0.94	-6.44	-5.7	-8.24	-22.14	-42.44	%	-6.97	-13.91	-16.89	-9.12	-30.98	-45.71
Annual	23.4	22.6	21.3	21.8	21.6	18.9	14.4	23.2	21.7	20.1	19.7	21.4	17.4	13.9
	%	-3.48	-9.17	-6.82	-7.62	-19.25	-38.73	%	-6.55	-13.15	-15.19	-7.47	-24.9	-39.88

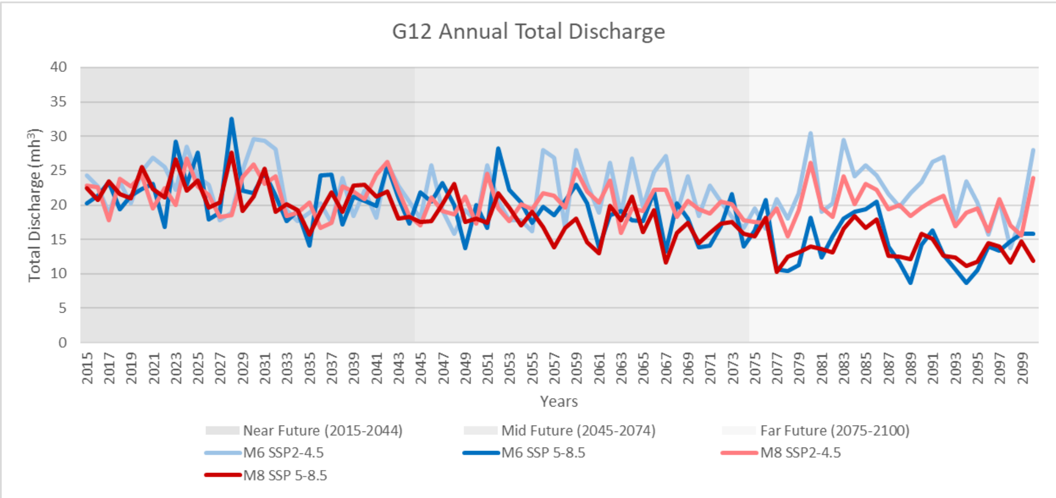


Figure 3.68 G12 subbasin annual total discharge in SSP2-4.5 and SSP5-8.5 scenarios

G18 Subbasin

Table 3.20 Seasonal and annual changes in G18 subbasin discharge with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)
Spring	5.1	4.9	4.6	4.8	4.8	4.5	3.4	4.9	4.7	4.4	4.3	4.7	4.1	3.4
	%	-3.95	-9.57	-5.33	-5.45	-11.83	-32.61	%	-4.79	-10.41	-11.49	-3.98	-16.09	-31.48
Summer	1.0	1.0	0.9	0.9	1.0	0.8	0.7	1.1	1.0	0.9	0.9	1.0	0.8	0.7
	%	-8.75	-14.1	-13.43	-5.66	-24.17	-37.64	%	-5.54	-13.93	-15.56	-6.6	-21.56	-36.54
Autumn	0.6	0.6	0.5	0.6	0.5	0.4	0.3	0.6	0.5	0.5	0.5	0.5	0.4	0.3
	%	-7.57	-16.15	-10.11	-15.82	-36.13	-46.54	%	-13.19	-20.63	-22.15	-14.6	-36.6	-49.44
Winter	5.6	5.6	5.3	5.4	5.2	4.5	3.3	5.6	5.3	4.9	4.7	5.2	3.9	3.1
	%	-0.17	-5.57	-4.55	-7.06	-20.61	-40.75	%	-6.2	-12.92	-15.72	-7.99	-29.59	-44.07
Annual	12.3	12.0	11.3	11.6	11.5	10.1	7.7	12.2	11.5	10.7	10.5	11.4	9.3	7.5
	%	-2.83	-8.48	-5.91	-6.74	-18.12	-37.46	%	-5.94	-12.4	-14.34	-6.6	-23.83	-38.63

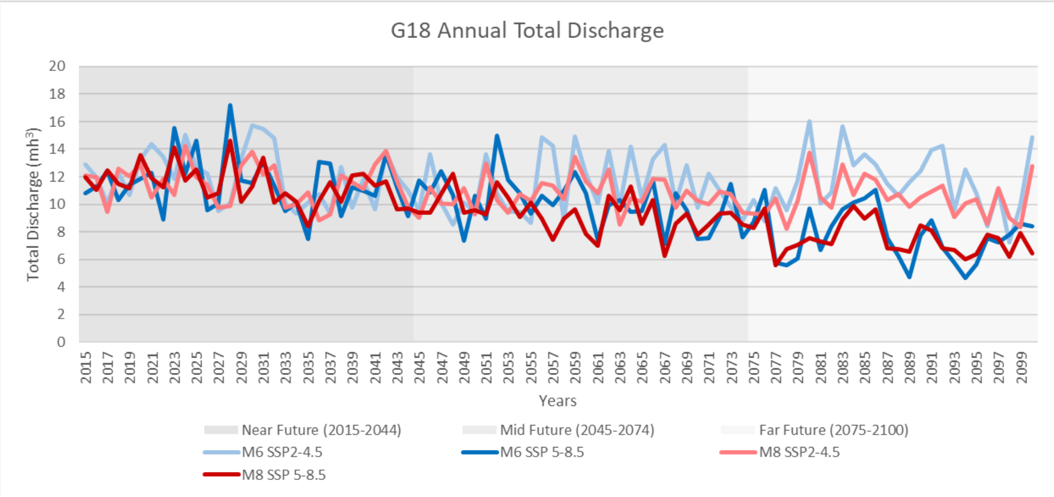


Figure 3.69 G18 subbasin annual total discharge in SSP2-4.5 and SSP5-8.5 scenarios

N14 Subbasin

Table 3.21 Seasonal and annual changes in N14 subbasin discharge with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)
Spring	14.9	14.4	13.5	14.3	14.3	13.6	10.5	14.3	13.8	13.0	12.9	14.0	12.5	10.3
	%	-3.15	-9.2	-3.86	-4.05	-8.49	-29.48	%	-3.69	-9.4	-10.18	-2.33	-12.95	-27.96
Summer	2.5	2.3	2.2	2.2	2.5	2.0	1.6	2.6	2.4	2.2	2.2	2.5	2.1	1.7
	%	-8.14	-13.12	-12.11	-3.2	-23	-36.64	%	-4.74	-12.89	-14.16	-4.28	-19.72	-35.27
Autumn	1.6	1.6	1.5	1.7	1.4	1.1	0.9	1.5	1.4	1.3	1.3	1.3	1.0	0.8
	%	-0.42	-9.03	1.93	-13.6	-35.07	-44.28	%	-10.96	-17.59	-17.14	-12.43	-36.18	-49.65
Winter	19.2	19.7	18.8	19.1	18.5	16.4	12.5	19.2	18.4	17.3	16.9	18.2	14.4	11.8
	%	2.83	-1.9	-0.11	-3.39	-14.56	-34.7	%	-3.87	-9.86	-11.78	-4.88	-25.09	-38.61
Annual	38.2	38.1	36.0	37.3	36.7	33.0	25.5	37.6	36.0	33.8	33.3	36.0	29.9	24.5
	%	-0.37	-5.79	-2.28	-4.07	-13.64	-33.21	%	-4.15	-10.21	-11.55	-4.18	-20.55	-34.78

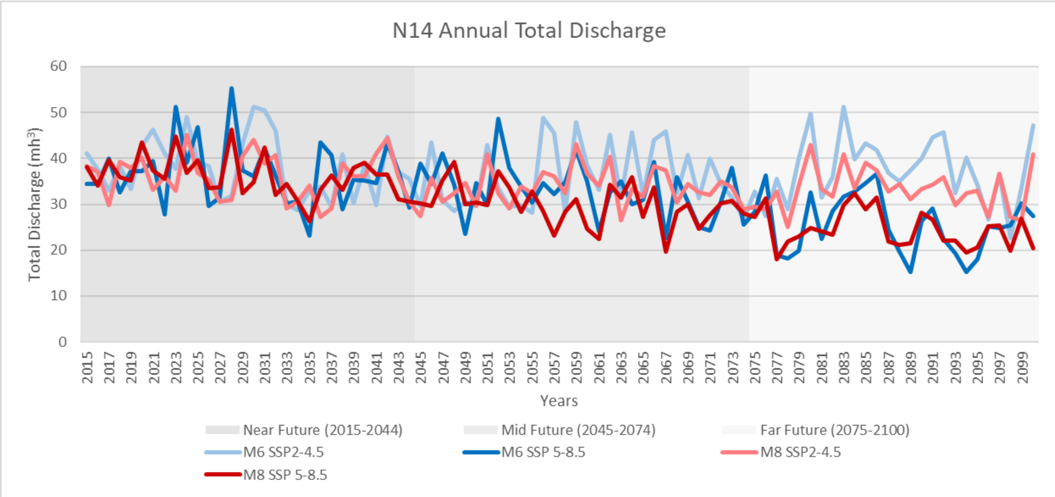


Figure 3.70 N14 subbasin annual total discharge in SSP2-4.5 and SSP5-8.5 scenarios

N15 Subbasin

Table 3.22 Seasonal and annual changes in N15 subbasin discharge with respect to historical period for M6 and M8 scenarios

		M6 - SSP 2-4.5			M6 - SSP 5.85				M8 - SSP 2-4.5			M8 - SSP 5-48.5		
	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	H	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)	Near Future (hm^3)	Mid Future (hm^3)	Far Future (hm^3)
Spring	12.6	12.2	11.5	11.9	12.1	11.6	8.9	4.0	3.7	3.5	3.4	4.0	3.2	2.5
	%	-3.55	-9.08	-5.28	-4.41	-8.34	-29.34	%	-6.13	-13.16	-13.7	-0.36	-18.61	-36.73
Summer	2.0	1.9	1.7	1.8	2.0	1.6	1.3	0.8	0.8	0.7	0.7	0.8	0.7	0.6
	%	-7.87	-12.94	-12.43	-2.85	-21.87	-35.07	%	-3.17	-9.08	-11.22	-3.19	-16.64	-28.12
Autumn	1.5	1.6	1.4	1.6	1.3	1.0	0.9	11.8	10.9	10.1	9.8	10.9	8.3	6.3
	%	1.3	-10.38	4.59	-12.7	-37.07	-43.5	%	-8.2	-14.96	-17.6	-7.94	-30.11	-47.03
Winter	17.8	18.3	17.4	17.8	17.7	15.6	12.2	16.9	16.4	15.7	15.4	16.5	14.6	12.6
	%	2.8	-2.17	-0.27	-0.84	-12.25	-31.45	%	-3	-6.75	-8.58	-2.15	-13.06	-25.34
Annual	34.0	33.9	32.0	33.1	33.0	29.7	23.3	33.5	31.7	30.0	29.3	32.1	26.8	21.9
	%	-0.26	-5.75	-2.63	-2.82	-12.49	-31.42	%	-5.21	-10.47	-12.44	-4.01	-19.83	-34.43

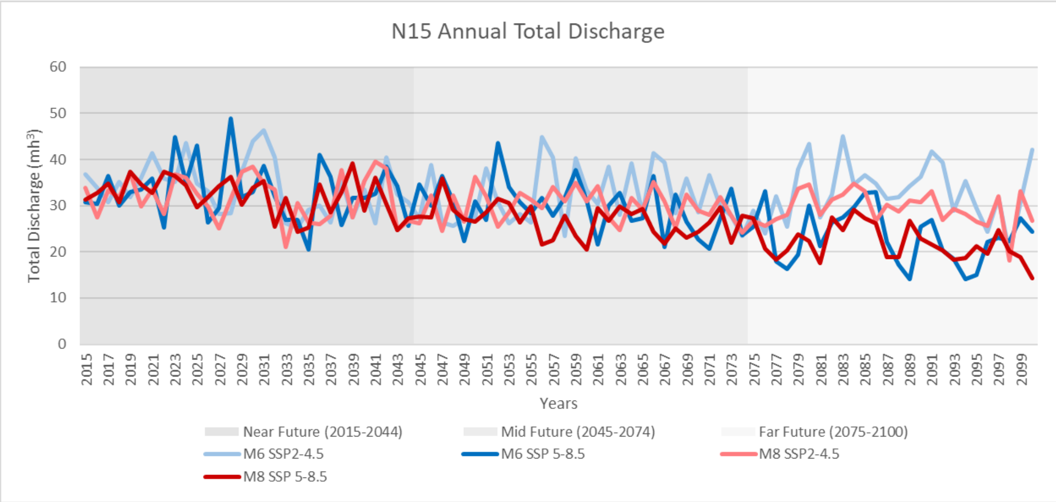


Figure 3.71 N15 subbasin annual total discharge in SSP2-4.5 and SSP5-8.5 scenarios

Percent changes in each subbasin can be visualized in Figure 3.50 and Figure 3.51 for M8 model ensemble SSP2-4.5 and SSP5-8.5 scenarios respectively.

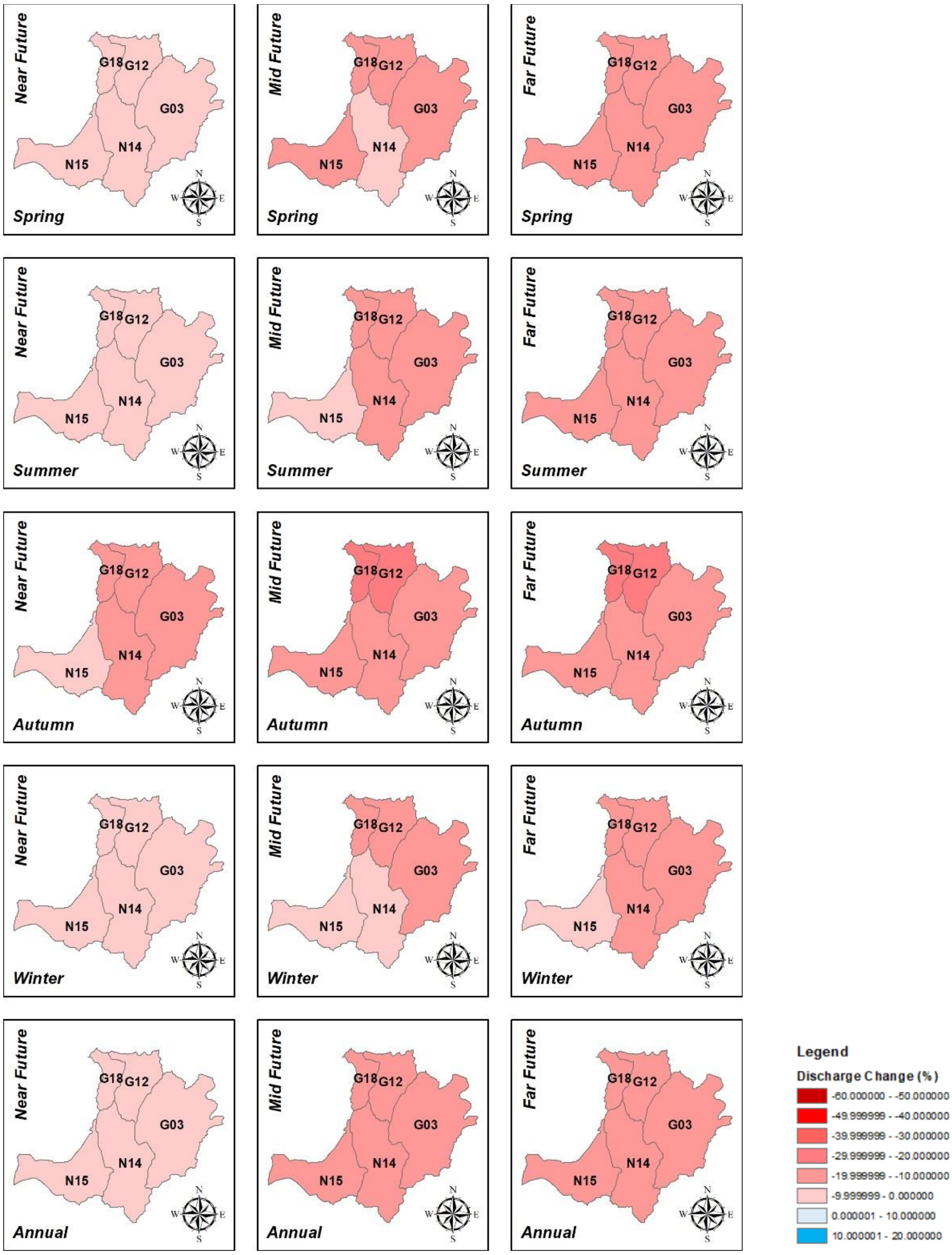


Figure 3.72 Seasonal discharge changes with respect to historical period in each subbasin – SSP2-4.5 scenario

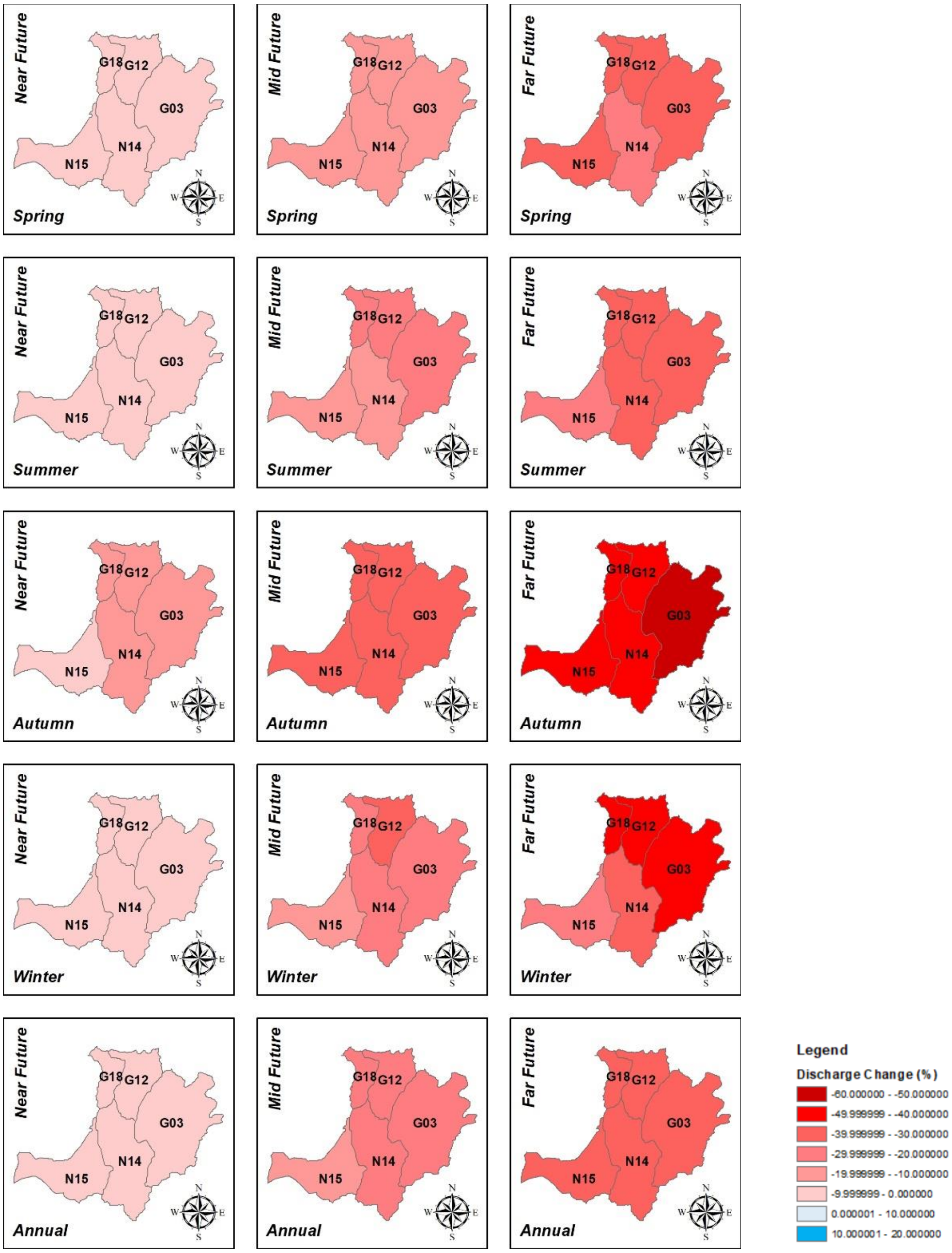


Figure 3.73 Seasonal discharge changes with respect to historical period in each subbasin – SSP5-8.5 scenario

3.4.3 Trend Analysis

Trends in M8 discharge are calculated for historical period and three future periods for each scenario (SSP2-4.5 and SSP5-8.5).

Trend test results for each subbasin are presented in Appendix – C on monthly, seasonal and annual basis. In the historical period there is no significant trend in discharge results. There is a significantly decreasing trend in summer months in the mid future with SSP2-4.5 scenario. In SSP5-8.5 scenario significant decrease is observed in Spring in near future and mid future summer, autumn and winter seasons.

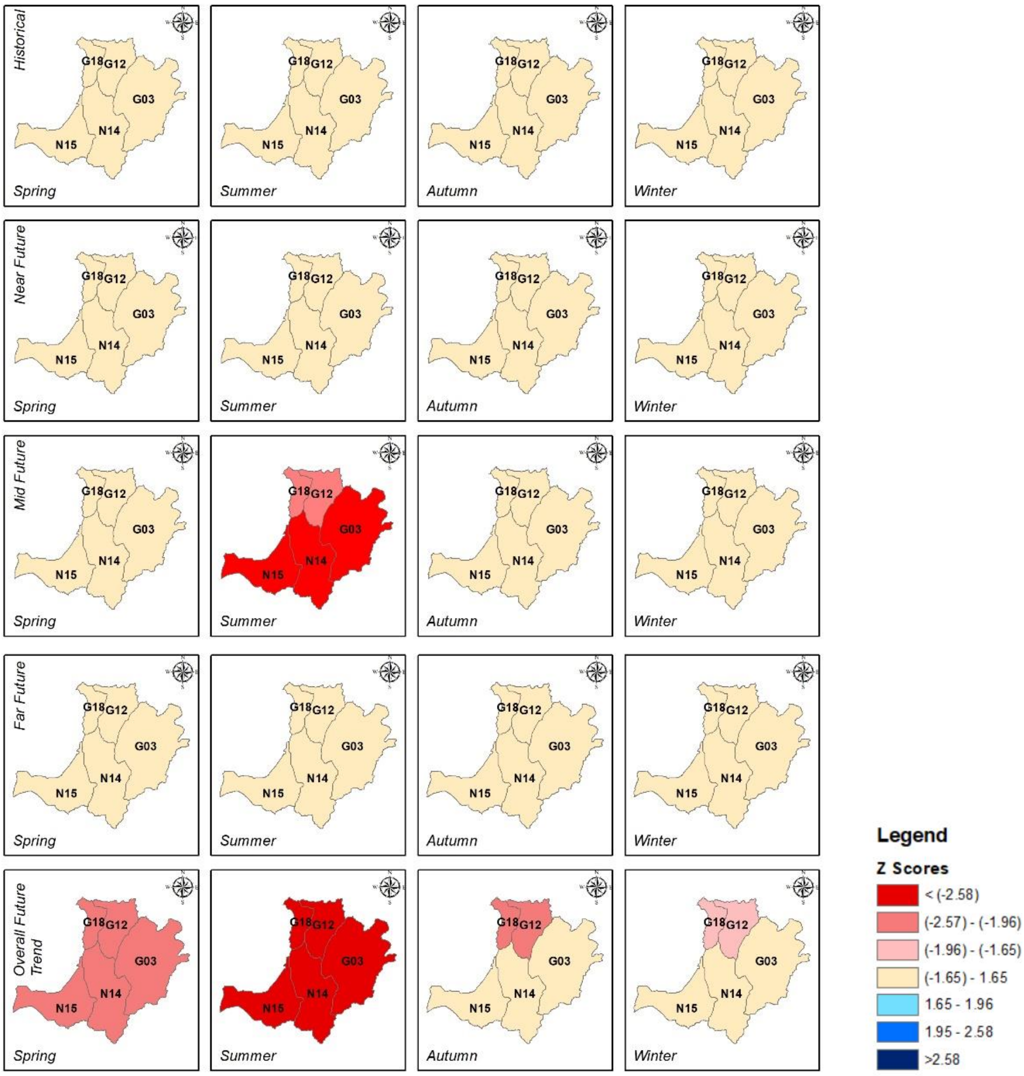


Figure 3.74 Seasonal discharge trends in subbasins for SSP2-4.5 Scenario

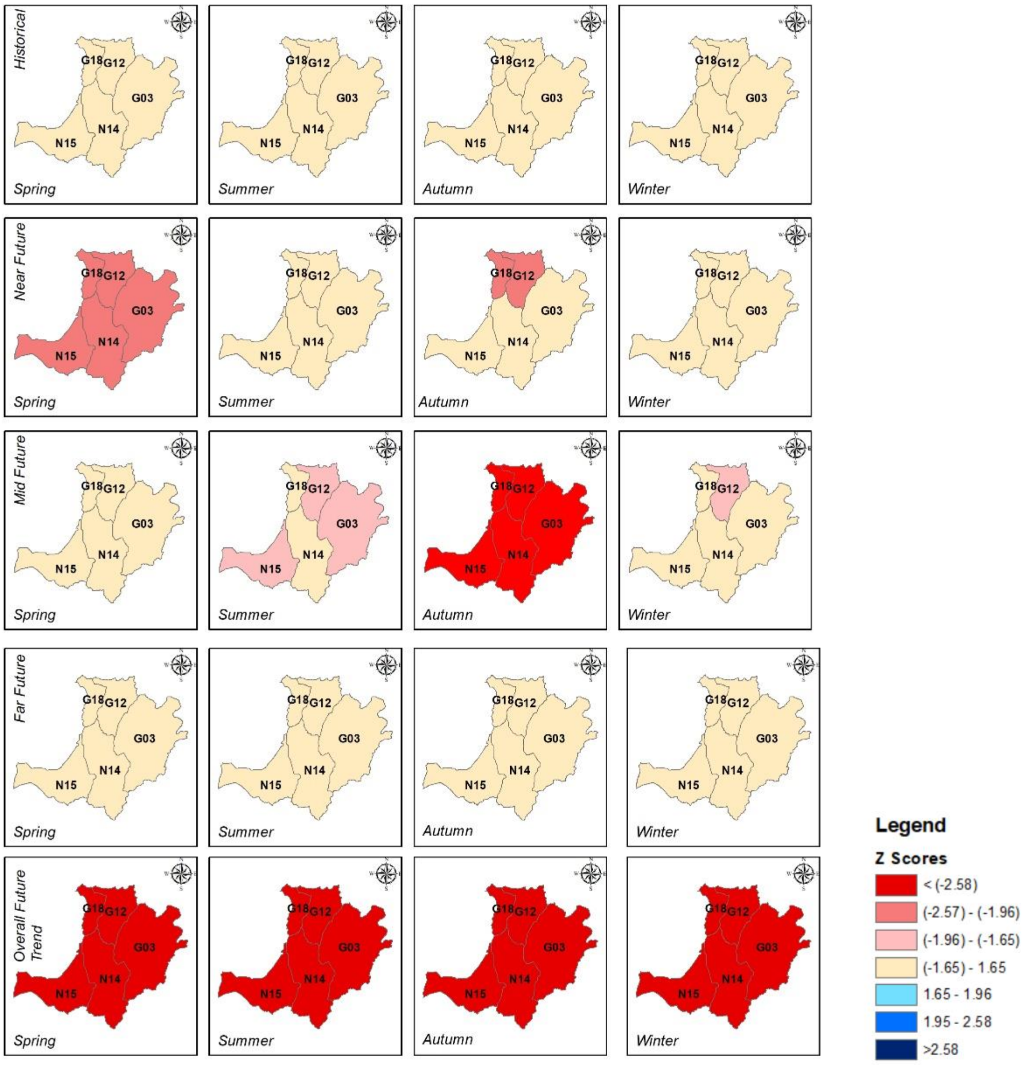


Figure 3.75 Seasonal discharge trends in subbasins for SSP5-8.5 Scenario

3.5 Havran Basin Summary Evaluations

After precipitation, temperature and discharge changes in each subbasin is evaluated, and annual mean changes in the Havran basin are calculated. It is seen from Table 3.23 and Table 3.24 that for both M6 and M8 total precipitation in the basin doesn't change to a great extent in M6 for SSP2-4.5 scenario. On the other hand, in M8 there is a small change in basin total precipitation. In SSP5-8.5 scenario total precipitation in the basin is decreasing in M6 and M8.

Table 3.23 M6 ensemble Annual Mean Precipitation Changes in Havran Basin

Historical Period	SSP2-4.5			SSP5-8.5		
	Near Future (mm)	Mid Future (mm)	Far Future (mm)	Near Future (mm)	Mid Future (mm)	Far Future (mm)
768.77	773.67	757.06	779.19	759.93	722.82	648.07
% Change	0.64	-1.52	1.35	-1.15	-5.98	-15.70

Table 3.24 M8 ensemble Annual Mean Precipitation Changes in Havran Basin

Historical Period	SSP2-4.5			SSP5-8.5		
	Near Future	Mid Future	Far Future	Near Future	Mid Future	Far Future
768.73	759.69	741.28	742.82	758.37	702.43	648.43
% Change	-1.18	-3.57	-3.37	-1.35	-8.62	-15.65

Overall temperatures in the basin are increasing in M6 and M8 for each scenario as given in Table 3.25 and Table 3.26 with both M6 and M8 model ensembles. The Increase is up to 5.61 ^{o}C with the M6 model ensemble and 5.3 ^{o}C with the M8 model ensemble by the end of the century.

Table 3.25 M6 ensemble Annual Mean Temperature Changes in Havran Basin

Historical Period	SSP2-4.5			SSP5-8.5		
	Near Future (°C)	Mid Future (°C)	Far Future (°C)	Near Future (°C)	Mid Future (°C)	Far Future (°C)
13.50	15.24	16.16	16.74	15.16	16.93	19.11
°C Change	1.74	2.66	3.24	1.65	3.42	5.61

Table 3.26 M8 ensemble Annual Mean Temperature Changes in Havran Basin

Historical Period	SSP2-4.5			SSP5-8.5		
	Near Future	Mid Future	Far Future	Near Future	Mid Future	Far Future
13.50	14.86	15.75	16.37	14.89	16.67	18.79
°C Change	1.36	2.26	2.87	1.40	3.17	5.30

Annual discharge in Havran basin is overall decreasing with both M6 and M8 model ensembles as it can be seen from Table 3.27 and Table 3.28 respectively. The decrease is at 34.69% with the M6 model ensemble and 36.17 % with the M8 model ensemble by the end of the century.

Table 3.27 M6 ensemble Annual Mean Discharge Changes in Havran Basin

Historical Period	SSP2-4.5			SSP5-8.5		
	Near Future	Mid Future	Far Future	Near Future	Mid Future	Far Future
38.77	38.24	36.12	37.30	36.76	32.87	25.32
% Change	-1.37	-6.84	-3.81	-5.21	-15.22	-34.69

Table 3.28 M8 ensemble Annual Mean Discharge Changes in Havran Basin

Historical Period	SSP2-4.5			SSP5-8.5		
	Near Future	Mid Future	Far Future	Near Future	Mid Future	Far Future
38.10	36.21	33.86	33.27	36.09	29.77	24.32
% Change	-4.97	-11.13	-12.69	-5.27	-21.86	-36.17

CHAPTER 4

DISCUSSION

In the beginning of this study, bias correction is performed with two different sets of observational data. Within the Havran basin, there are no meteorological observation stations having long-term data record. Therefore, data taken from 2 observation stations that are located outside of the basin are employed in bias correction. Overall bias correction results showed increasing RMSE and decreasing correlations between observed and bias corrected data for precipitation. With the temperature data there was no such problem. The reason might be that the stations are not within the borders of the basin so that their representational capability of the basin is poorer. Therefore, station observation dataset is replaced with ERA5 Land data.

Among the bias correction applied to Raw GCM outputs, bias correction with ERA5 Land data results showed that correlations are increasing and RMSE values are slightly decreasing between observed and bias corrected data for precipitation. Therefore, the remaining evaluations are made with the bias correction results using ERA5 Land variables.

Among three different bias correction methods, there is a very small difference between QDM and DQM methods which outperform QM. Frequency of precipitation data for annual maximums is shown and it was determined that the difference between QDM and DQM is not that obvious. Despite their difference is not that distinct is shown that they both perform better with annual maximum precipitations than QM method. Among QDM and DQM, QDM method is chosen for further studies within the scope of this thesis.

Nine model scenarios are constructed for GR2M hydrological model. Precipitation and temperature data are evaluated accordingly. For each model scenario, calculated precipitation, temperature and discharge data are compared with observational data.

It is seen that ensemble models are fitting better with observed data. Also, as more bias corrected CMIP6 model output is incorporated in the model, RMSE is getting lower and correlation between observed and modeled data is higher. Therefore, two ensembles M6 and M8 models are employed in evaluation of future variables. Between the two, M8 has higher correlations with the observational data for precipitation, temperature and discharge on the scale of each subbasin.

Precipitation, temperature and discharge results are evaluated for five subbasins of Havran basin individually. After that overall conclusions are drawn for the Havran basin.

Precipitation values showed both increasing and decreasing characteristics within all subbasins especially in SSP2-4.5 scenario. The worst-case scenario SSP5-8.5 suggests the decrease to be up to 17% on annual basis. It was found that overall, in Havran basin annual precipitation changes are not noticeable in SSP2-4.5 scenario. In SSP5-8.5 scenario basin mean precipitation values are decreasing by 15% by the end of the century which corresponds to an annual decrease of 120 mm. In Havran basin, precipitation values do not show statistically significant change in all subbasins for all future periods which show similar characteristics with each other. Only significant decrease is found to occur in Spring season of mid future period of SSP2-45 scenario where the significant decrease is shifted to the Autumn season in SSP5-8.5 scenario. When the overall future period is subjected to trend analysis, all subbasins for each season showed a statistically significant decrease.

Overall warming trend is observed in both SSP2-4.5 and SSP5-8.5 scenarios. Spring temperature rises are up to 5^{o}C with the worst-case scenario and 2.8 ^{o}C with SSP2-4.5 by the end of the century. In summer months the increase in the temperature is found to be up to 7.5 ^{o}C with SSP5-8.5 scenario in the subbasin scale whereas SSP2-4.5 scenario results showed an increase in temperatures at 3.8^{o}C at the end of the projection period. In winter the most drastic increase in the temperatures is estimated as 4.3 ^{o}C with the SSP5-8.5 scenarios and SSP2-4.5 scenario reveals an increase by 3 ^{o}C on a subbasin scale. Average annual temperature increase in the basin is changing between 2.87^{o}C and 5.61 ^{o}C for SSP2-4.5 and SSP5-8.5 scenarios respectively. Temperature changes generally showed statistically significant increase for each subbasin for each future period. In SSP2-4.5 scenario, winter and spring seasons of near future and spring and autumn seasons of mid future for each subbasin showed different characteristics in terms of the increasing trend in temperature. There was no trend in the spring and autumn seasons of far future period. Also, there is a statistically significant increase for each subbasin when the whole future period is subjected to trend analysis. In SSP5-8.5 scenario all subbasins for all seasons showed statistically increasing trend in each future period.

In the near future, annual total discharge for Havran basin is overall decreasing through the end of the century. In Spring, the decrease is found to be up to 34 % in subbasin scale at the end of the century with respect to SSP5-8.5 scenario. Within all future periods significant decreasing trend is dominating. On an annual basis for Havran basin, SSP2-4.5 scenario suggests a decrease of discharge between 3.8-12.7% with SSP2-4.5 scenario and 35% decrease with SSP5-8.5 scenario by the end of the century. Decrease in discharge is not statistically significant in SSP2-4.5 scenario except for summer months of mid future period. In SSP5-8.5 scenario, in near future, discharge in all subbasins significantly decreases in spring season. Within the same future period for autumn season the decrease is pronounced on the northern subbasins of Havran. Trend in decrease continues in the mid future summer months and the degree of the decrease is stronger in autumn months. When overall future period is subjected to trend analysis, there is a significant decrease in each subbasin for all seasons.

Results are compared with the project of the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, GDWM, 2016), Impact of Climate Change on Water Resources Project. In the project, CMIP5 models have been employed in future projections. It is stated by Bagçacı (2021) that CMIP6 products result in a better performance especially for precipitation. Also, CMIP6 models show less intermodal variability indicating there is an improvement in the climate change signal when obtained from CMIP6 models in comparison to CMIP5 models.

Therefore, the climate change studies in the Havran region of Kuzey Ege River basin have been updated with this study. In this study, worst case temperature increase is more pronounced within Havran basin (5.3^{o}C) than what was found for Kuzey Ege basin (5.2^{o}C) in the project of GDWM. In the worst-case scenario, it was found that a 100mm decrease in precipitation is expected in Kuzey Ege basin whereas the most drastic decrease found in this study was 120 mm with SSP5-8.5 scenario. As similar to the study conducted in Kuzey Ege river basin, discharge amounts are decreasing and the decrease is expected to be at 36.17 % by the end of the century in the worst-case scenario.

SUMMARY AND CONCLUSION

In this study, two different ensemble of CMIP6 GCMs are employed in future projections of precipitation, temperature and discharge in Havran basin. Those projections are evaluated in three different future scenarios namely Near Future (2015-2044), Mid Future (2045-2074) and Far Future (2075-2100).

Raw GCM outputs are post-processed with three different quantile mapping bias correction methods. QDM method is chosen among them for future evaluations of changing precipitation, temperature and discharge. Between all individual and ensemble model performances in predicting precipitation, temperature and total discharge of the basin are evaluated against observed data that is averaged on each subbasin.

Key findings of this study are given below.

- Among quantile mapping based bias correction methods QDM and DQM perform better than QM for most of the climate models. Among QDM and DQM method although the difference is not very distinct, QDM method is chosen to be used as it preserves the values within all quantiles especially for extreme values
- The use of individual models results in the decrease of modeling performance. Ensemble modeling approach increases the model performance and provides more similar results to observed climatic variables. Also, as more models are incorporated into the ensemble, modeling performance increases.
- As a consequence of overall increasing temperature and decreasing precipitation in Havran basin, discharge is also decreasing in near, mid and far future periods for both SSP scenarios.

The results have essentially important as climate models are incorporated into the hydrological model to understand the future changes within a basin where agricultural activities are dominating. Considering the changes in precipitation and temperature, in the future, it may be necessary to change the crop pattern by focusing on plants with low water demand and less sensitive to impacts of climate change. Also, the current applications used in irrigation could be replaced with more effective techniques considering the decreasing water availability in the future.

While in this study number of GCM outputs are employed in the evaluation of future changes in precipitation, temperature and discharge, further studies could be conducted using different combinations of more GCM incorporation. In this study high resolution data was obtained using quantile mapping based bias correction methods. In the future, a similar study may be conducted again when CMIP6 RCMs are available.

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APPENDICES

A. Individual Model Statistics

Bias Correction Performed with Gridded ERA5 – Land Data

Mean Model performance statistics for ERA5 Land total precipitation

	ACCESS CM2				CNRM CM6 1 HR			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	**62.6**	**63.2**	**63.2**	**63.2**	**88.1**	**59.7**	**59.8**	**59.8**
PBIAS	**-13.6**	**-0.1**	**-0.2**	**0.0**	**70.2**	**-0.1**	**-0.2**	**0.0**
rSD	**0.9**	**0.9**	**0.9**	**0.9**	**1.3**	**0.9**	**0.9**	**0.9**
r	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
KGE	**0.3**	**0.4**	**0.4**	**0.4**	**0.02**	**0.4**	**0.4**	**0.4**

	EC Earth3				EC Earth3 Veg			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	**56.9**	**59.0**	**59.0**	**59.0**	**58.7**	**60.4**	**60.5**	**60.5**
PBIAS	**-14.4**	**0.0**	**0.0**	**0.0**	**-12.1**	**-0.1**	**-0.2**	**0.0**
rSD	**0.8**	**1.0**	**1.0**	**1.0**	**0.9**	**1.0**	**1.0**	**1.0**
r	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
KGE	**0.4**	**0.5**	**0.5**	**0.5**	**0.4**	**0.5**	**0.5**	**0.5**

	GFDL ESM4				HadGEM3 GC31 LL			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	**57.6**	**61.2**	**61.3**	**61.3**	**61.5**	**60.8**	**60.8**	**60.8**
PBIAS	**-9.5**	**-0.1**	**-0.2**	**0.0**	**-18.8**	**0.0**	**-0.2**	**0.0**
rSD	**0.7**	**0.9**	**0.9**	**0.9**	**0.9**	**1.0**	**1.0**	**1.0**
r	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**
KGE	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**

	HadGEM3 GC31 MM				MIROC6			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	**61.5**	**59.9**	**57.8**	**57.8**	**56.1**	**58.4**	**58.4**	**58.4**
PBIAS	**-18.8**	**-5.3**	**-0.2**	**-0.2**	**-18.0**	**0.1**	**-0.2**	**0.0**
rSD	**0.9**	**1.0**	**1.0**	**1.0**	**0.7**	**0.9**	**0.9**	**0.9**
r	**0.4**	**0.5**	**0.5**	**0.5**	**0.4**	**0.4**	**0.4**	**0.4**
KGE	**0.4**	**0.5**	**0.5**	**0.5**	**0.3**	**0.4**	**0.4**	**0.4**

Mean Model performance statistics for ERA5 Land total precipitation *continued*

	MRI ESM2 0				UKESM1 0 LL			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	**57.5**	**60.2**	**60.2**	**60.2**	**57.5**	**57.5**	**57.5**	**57.5**
PBIAS	**-7.2**	**0.0**	**-0.2**	**0.0**	**-16.2**	**-0.1**	**-0.2**	**0.0**
rSD	**0.8**	**0.9**	**0.9**	**0.9**	**1.0**	**1.1**	**1.1**	**1.1**
r	**0.5**	**0.4**	**0.4**	**0.4**	**0.5**	**0.6**	**0.6**	**0.6**
KGE	**0.4**	**0.4**	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**

Mean Model performance statistics for ERA5 Land average temperature

	BCC CSM 2 MR				CanESM5			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	4.58	4.26	4.26	4.26	3.31	2.04	2.04	2.04
PBIAS	15.86	-0.10	-0.10	-0.10	19.03	0.00	0.00	0.00
rSD	0.69	1.07	1.07	1.07	0.94	1.00	1.00	1.00
r	0.85	0.84	0.84	0.84	0.96	0.96	0.96	0.96
KGE	0.61	0.82	0.82	0.82	0.79	0.96	0.96	0.96

	CESM2				CESM2 WACCM			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	3.64	2.11	2.11	2.11	3.54	2.03	2.03	2.03
PBIAS	19.64	0.00	0.00	0.00	19.98	0.00	0.00	0.00
rSD	1.13	1.01	1.01	1.01	1.09	1.00	1.00	1.00
r	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
KGE	0.74	0.96	0.96	0.96	0.77	0.96	0.96	0.96

	CNRM CM6 1				CNRM ESM2 1			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	2.95	2.12	2.12	2.12	3.49	2.17	2.17	2.17
PBIAS	13.65	-0.12	-0.12	-0.12	19.71	0.00	0.00	0.00
rSD	0.97	1.00	1.00	1.00	1.00	1.01	1.01	1.01
r	0.96	0.96	0.96	0.96	0.95	0.96	0.96	0.96
KGE	0.84	0.95	0.95	0.95	0.79	0.95	0.95	0.95

	EC Earth3				EC Earth3 Veg			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	2.84	2.08	2.08	2.08	2.83	2.08	2.08	2.08
PBIAS	2.89	0.00	0.00	0.00	7.55	0.00	0.00	0.00
rSD	1.19	1.01	1.01	1.01	1.16	1.01	1.01	1.01
r	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
KGE	0.79	0.96	0.96	0.96	0.81	0.96	0.96	0.96

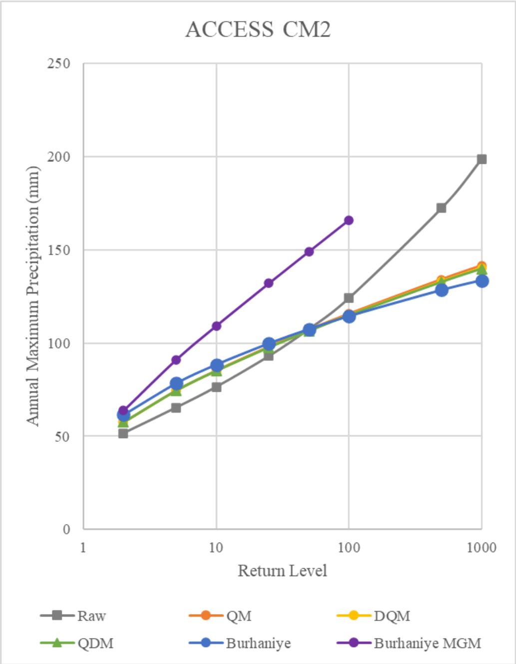
	HadGEM3 GC31 LL				HadGEM3 GC31 MM			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	2.75	2.37	2.37	2.37	2.65	2.23	2.23	2.23
PBIAS	2.12	0.00	0.00	0.00	-3.68	0.00	0.00	0.00
rSD	0.85	1.00	1.00	1.00	0.96	0.99	0.99	0.99
r	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95
KGE	0.82	0.95	0.95	0.95	0.89	0.95	0.95	0.95

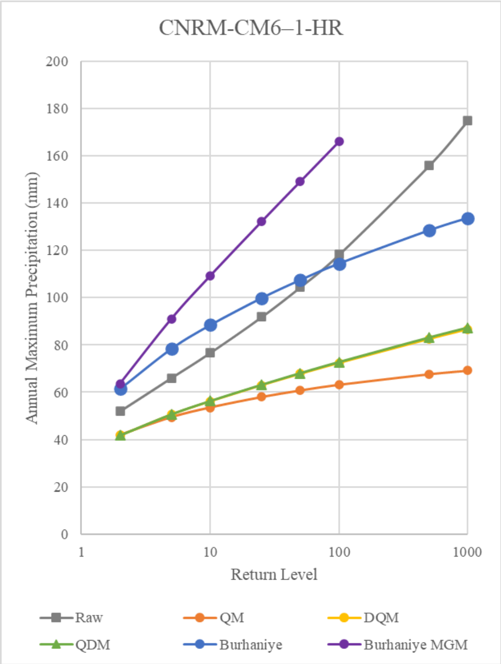
Mean Model performance statistics for ERA5 Land average temperature *continued*

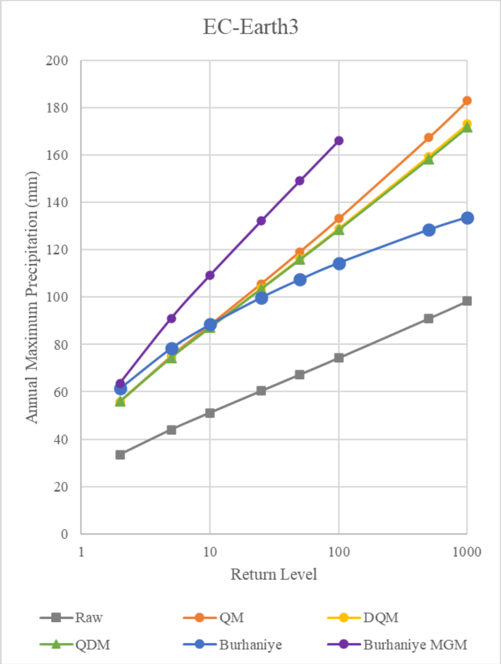
	MPI ESM1 2 HR				MRI ESM2 0			
Parameters	**Raw**	**QM**	**QDM**	**DQM**	**Raw**	**QM**	**QDM**	**DQM**
RMSE	3.19	1.97	1.97	1.97	2.81	2.13	2.13	2.13
PBIAS	15.29	0.00	0.00	0.00	9.92	0.00	0.00	0.00
rSD	1.12	1.00	1.00	1.00	0.88	1.00	1.00	1.00
r	0.96	0.96	0.96	0.96	0.95	0.96	0.96	0.96
KGE	0.78	0.96	0.96	0.96	0.81	0.96	0.96	0.96

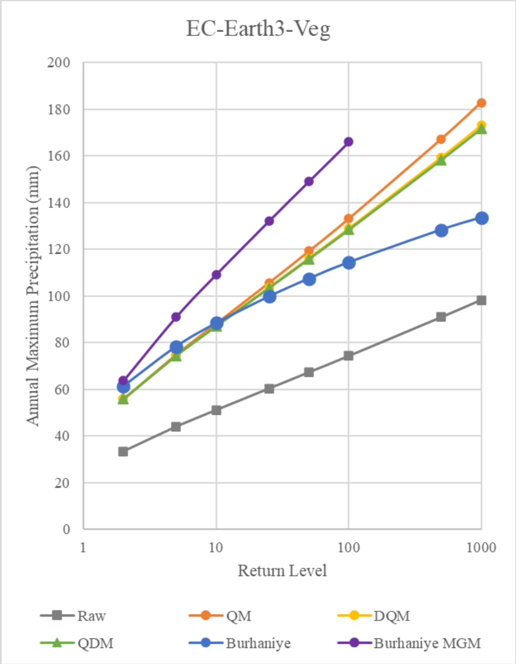
	NorESM2 MM			
Parameters	**Raw**	**QM**	**QDM**	**DQM**
RMSE	2.98	2.07	2.07	2.07
PBIAS	14.39	0.00	0.00	0.00
rSD	0.97	1.01	1.01	1.01
r	0.96	0.96	0.96	0.96
KGE	0.82	0.96	0.96	0.96

Frequency Curves for each bias correction method for each GCM data for Station Observations – Burhaniye Station

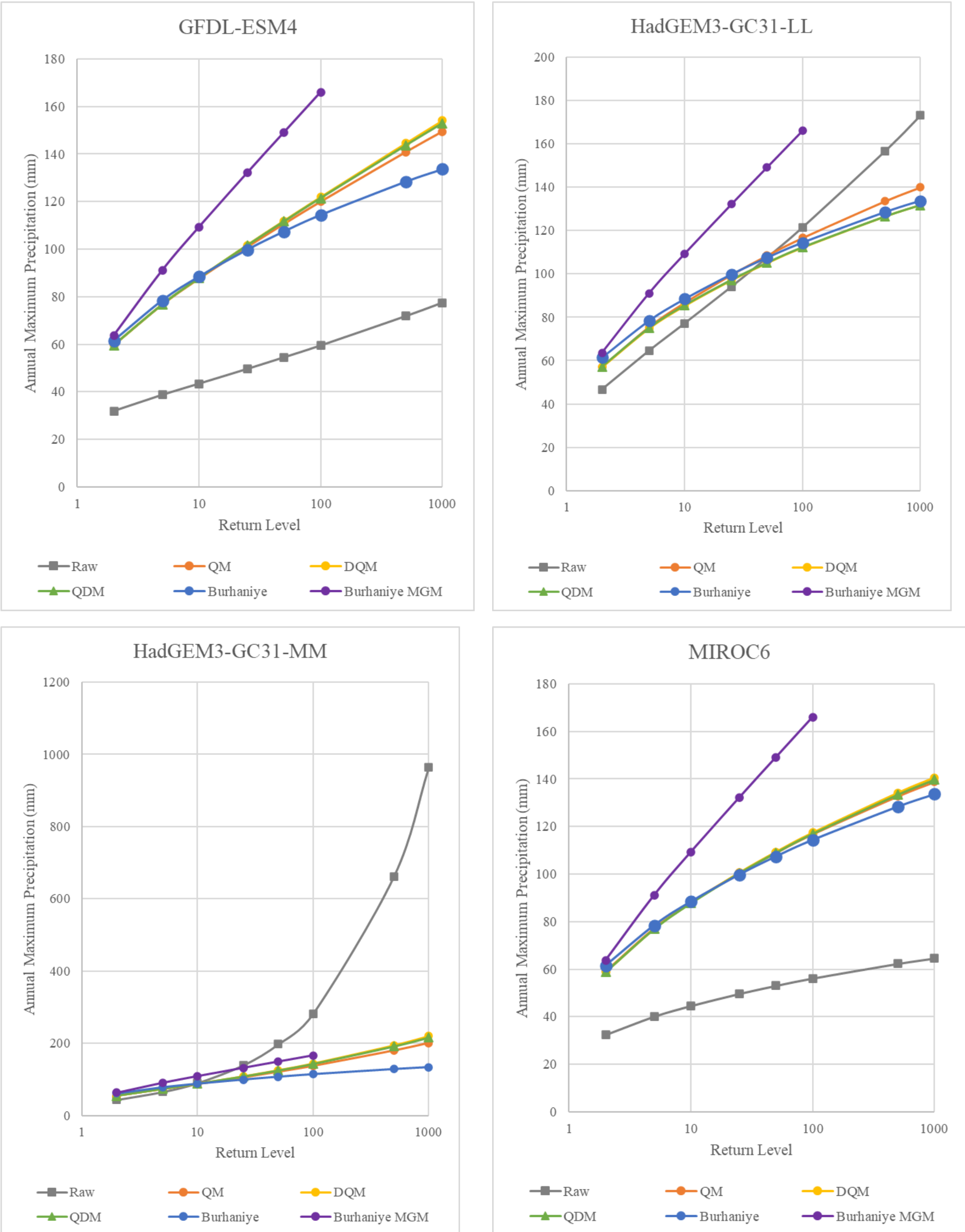




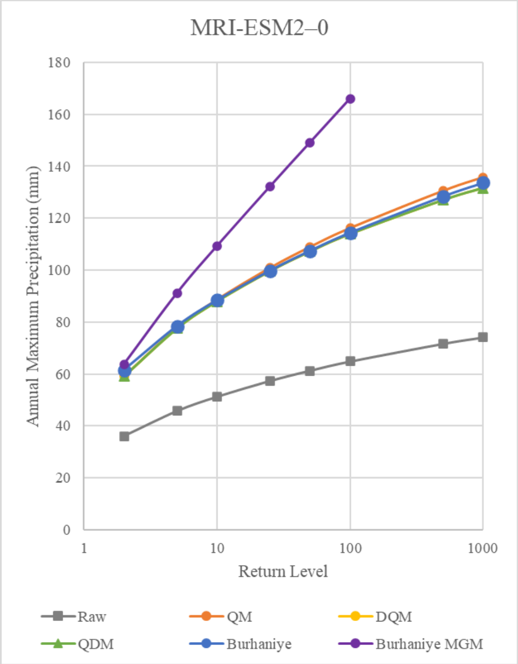


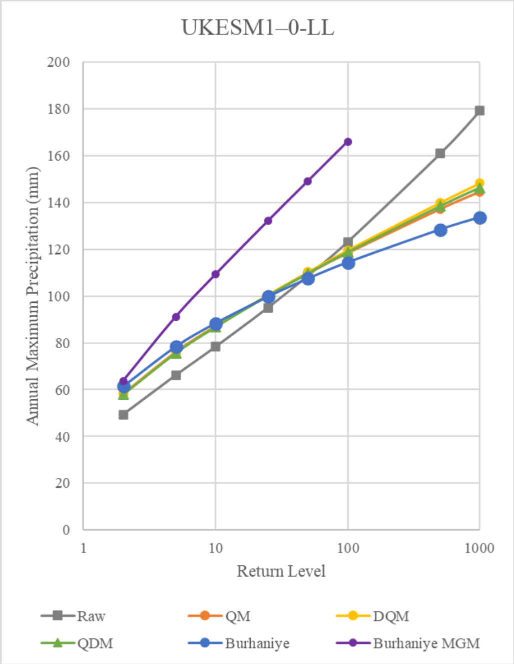


Frequency Curves for each bias correction method for each GCM data for Station Observations – Burhaniye Station - *continued*

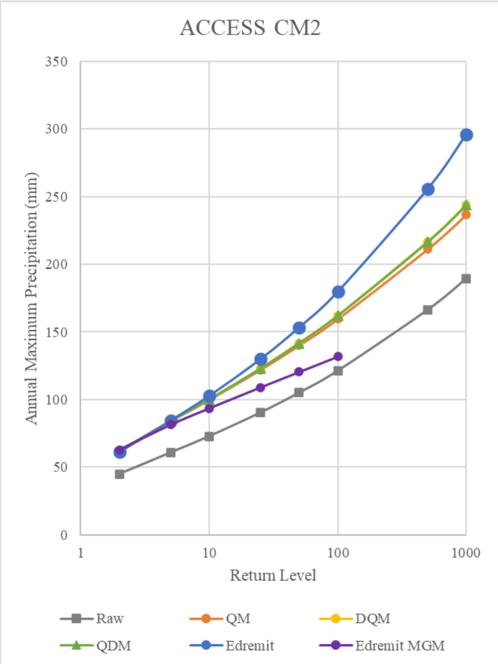


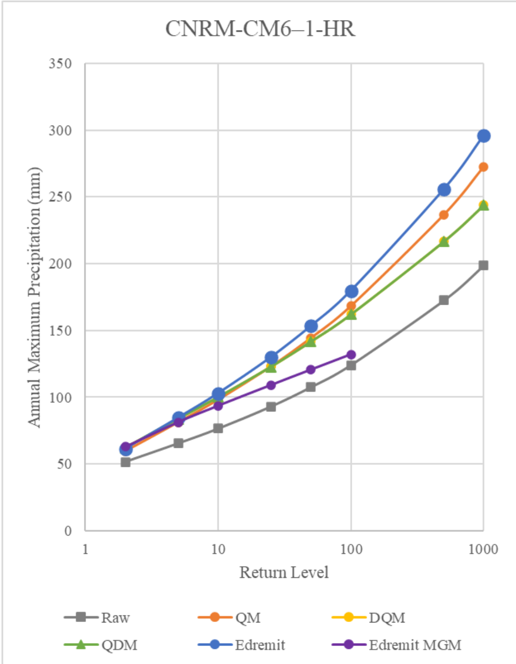
Frequency Curves for each bias correction method for each GCM data for Station Observations – Burhaniye Station - *continued*

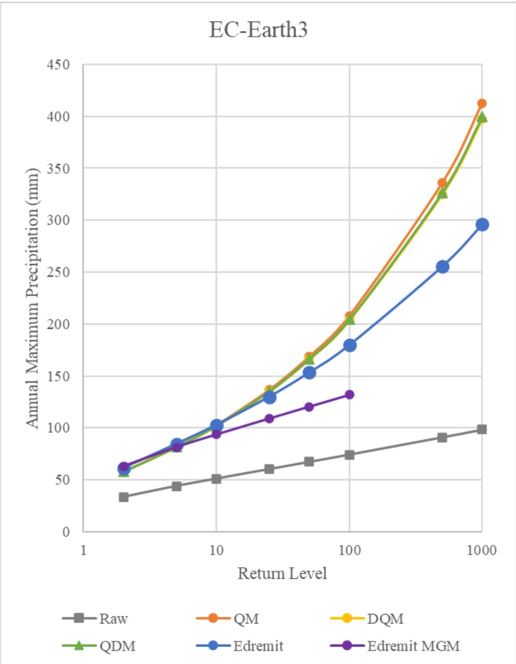


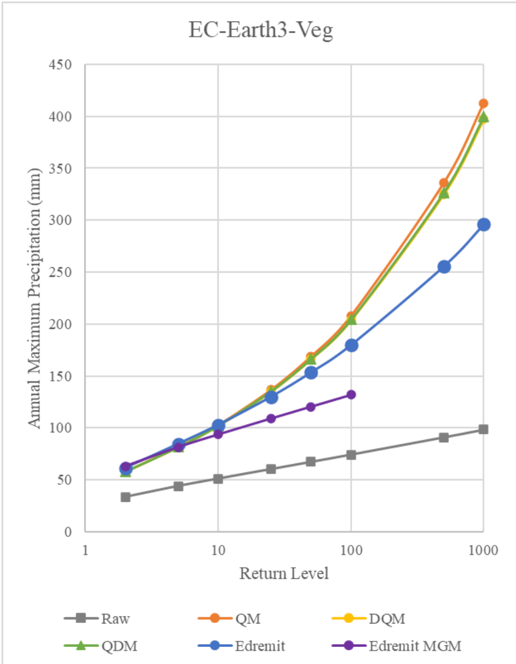


Frequency Curves for each bias correction method for each GCM data for Station Observations – Edremit Station

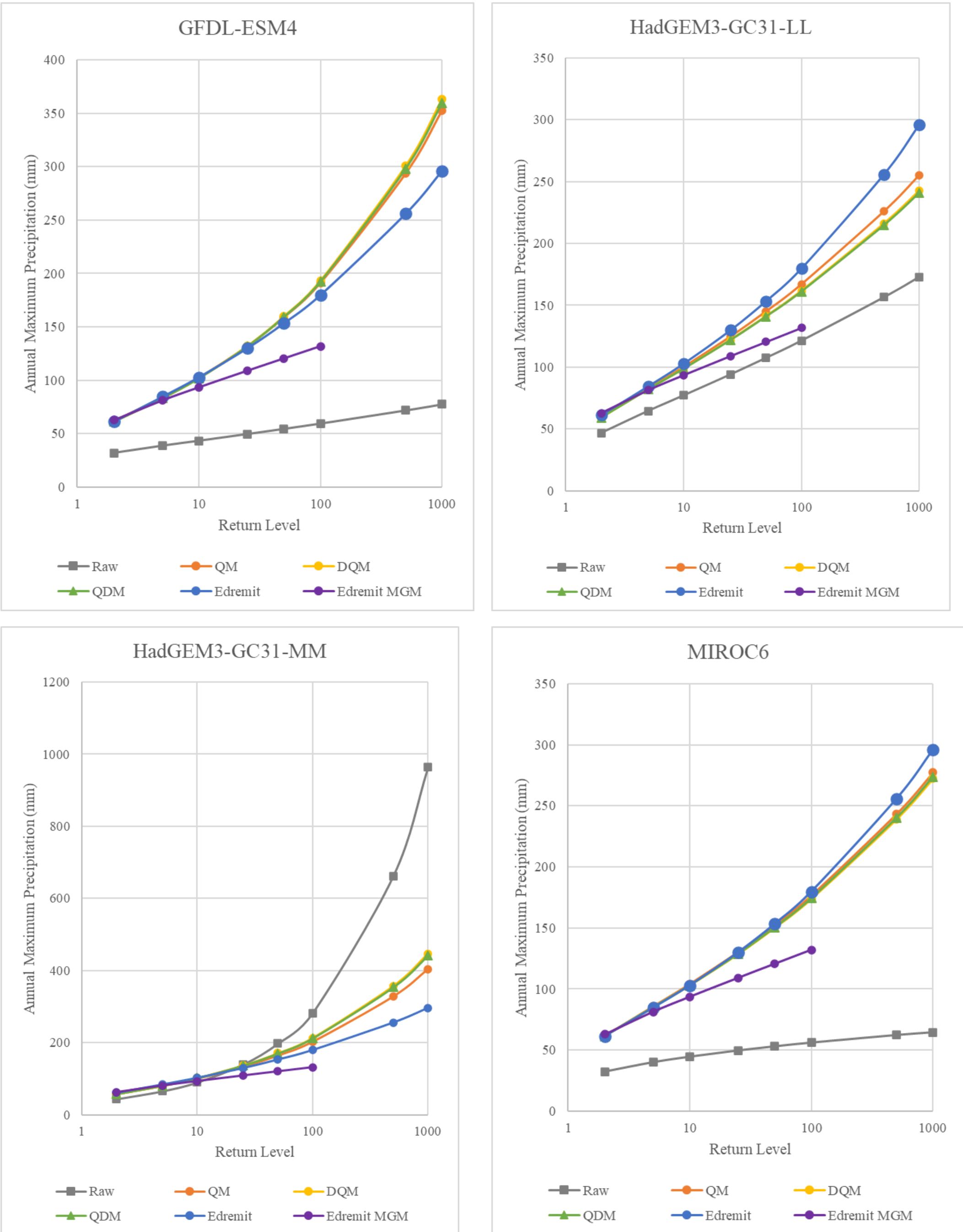




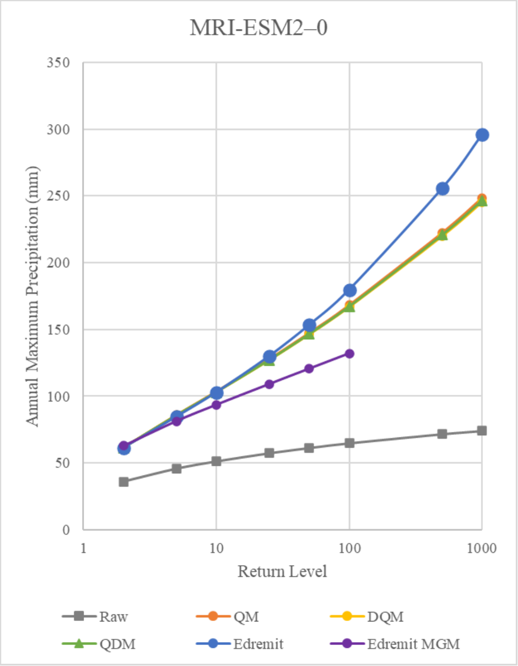


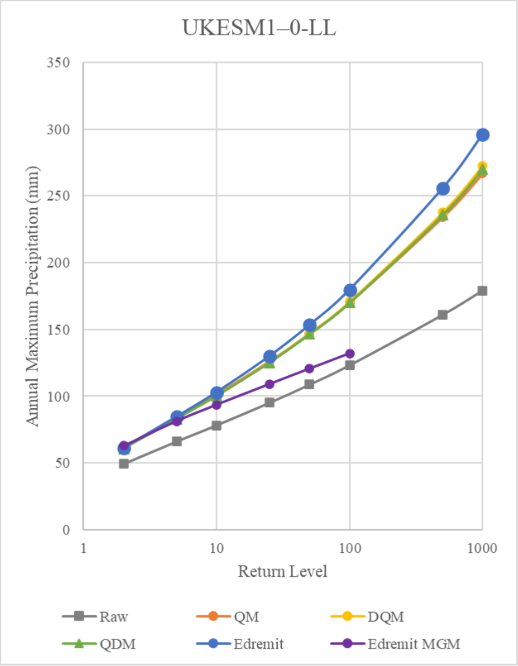


Frequency Curves for each bias correction method for each GCM data for Station Observations – Edremit Station - *continued*

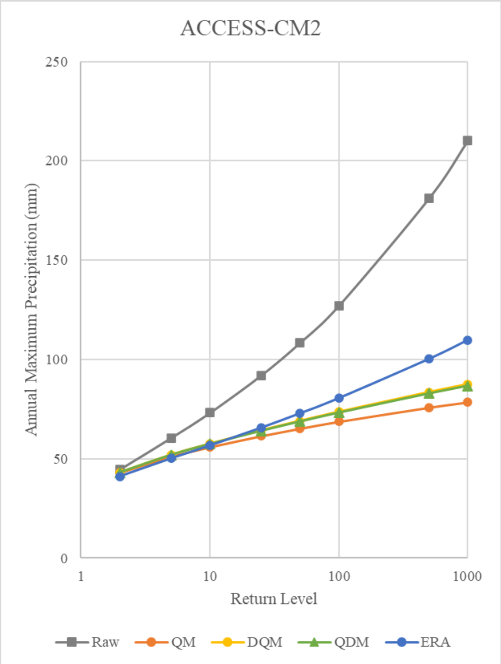


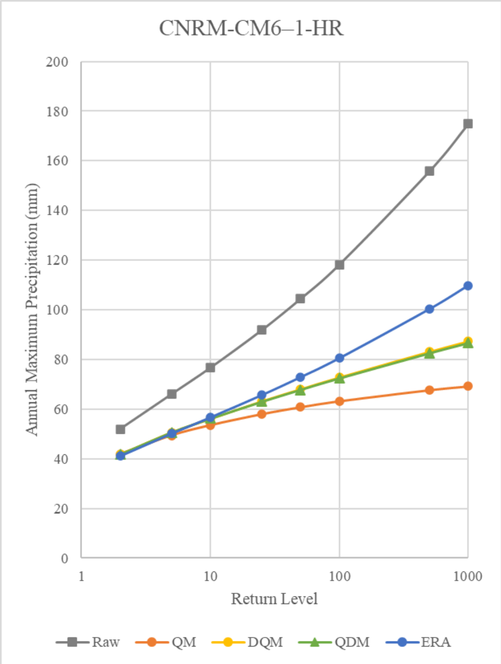
Frequency Curves for each bias correction method for each GCM data for Station Observations – Edremit Station - *continued*

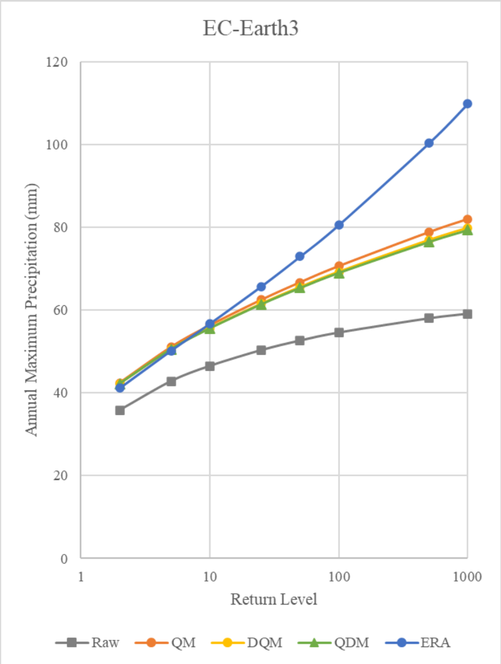


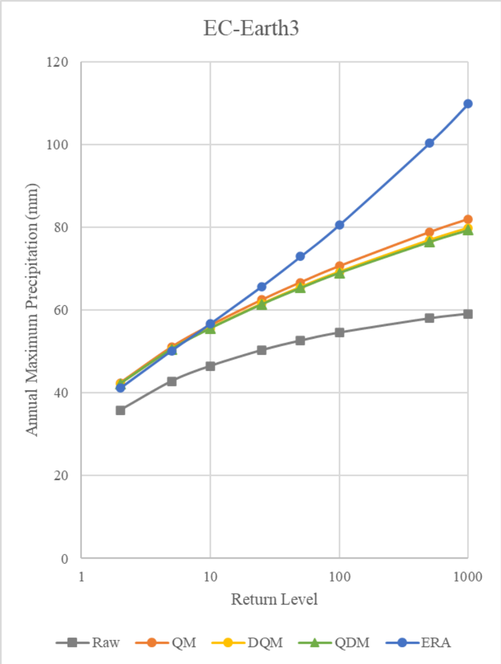


Frequency Curves for each bias correction method for each GCM data for ERA5 Land Observations

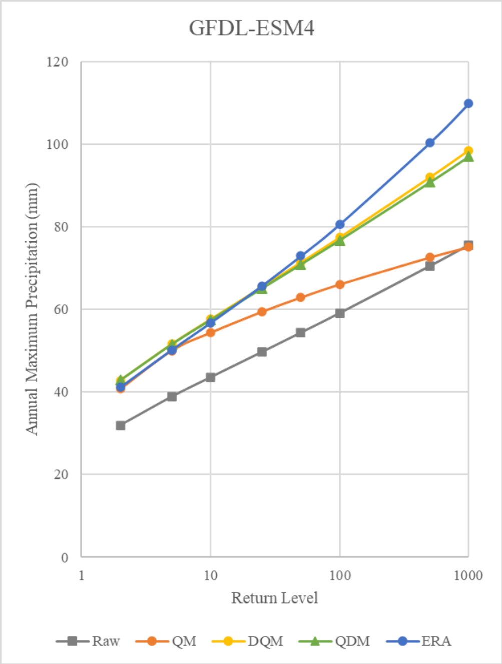


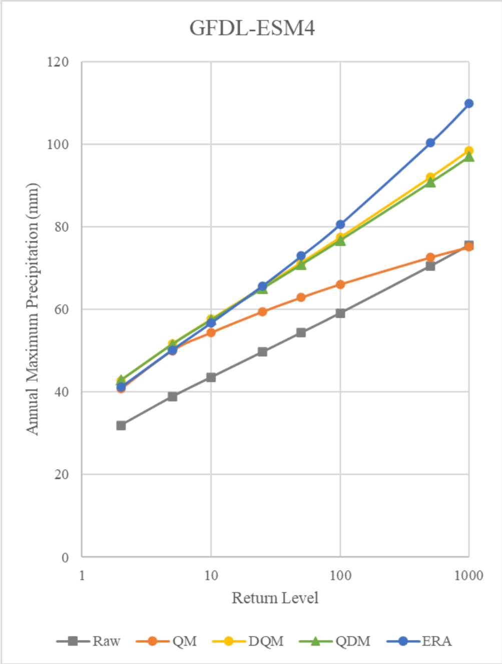


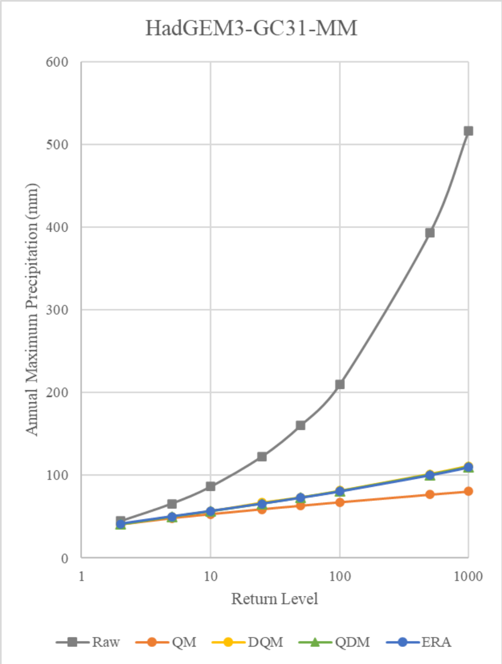


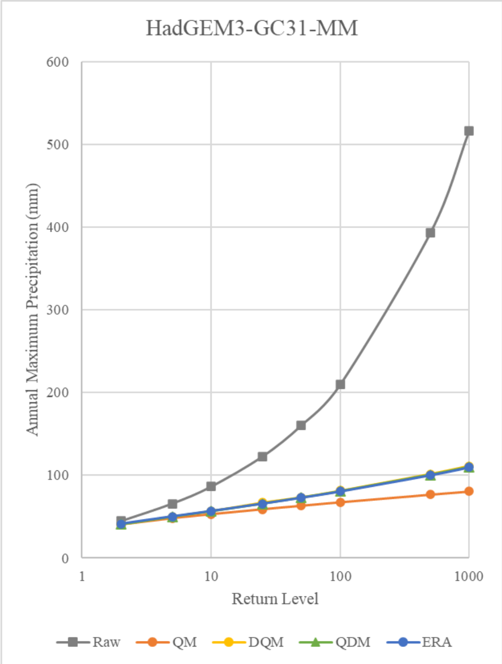


Frequency Curves for each bias correction method for each GCM data for ERA5 Land Observations - *continued*

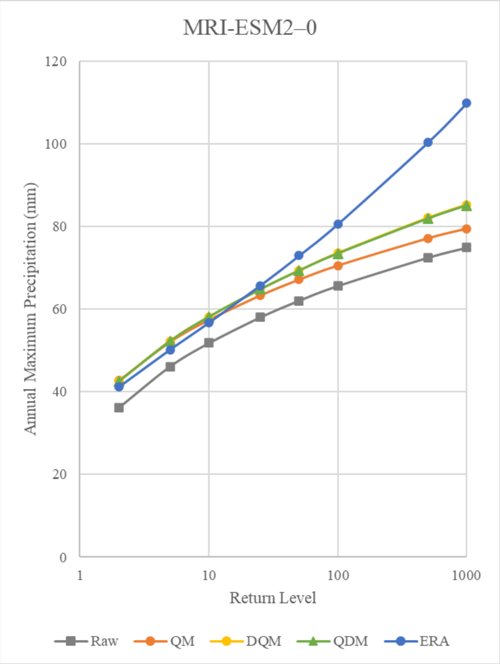


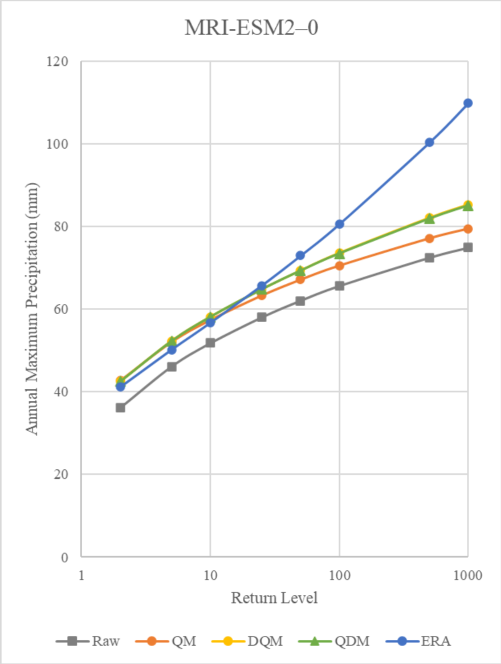






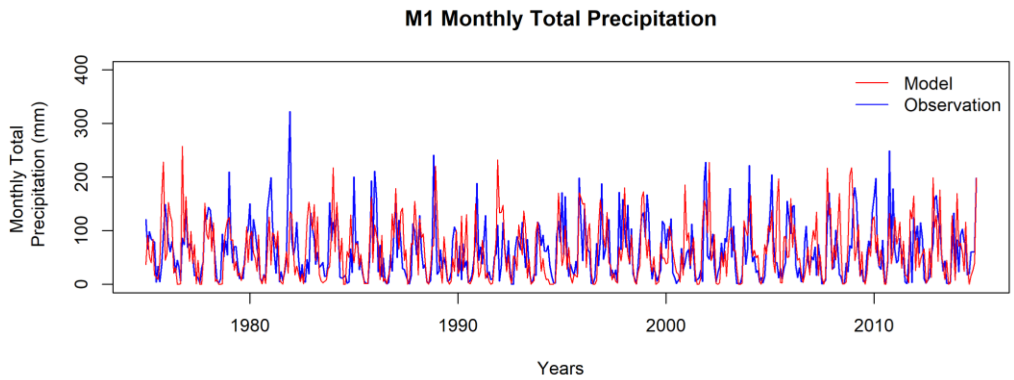
Frequency Curves for each bias correction method for each GCM data for ERA5 Land Observations - *continued*

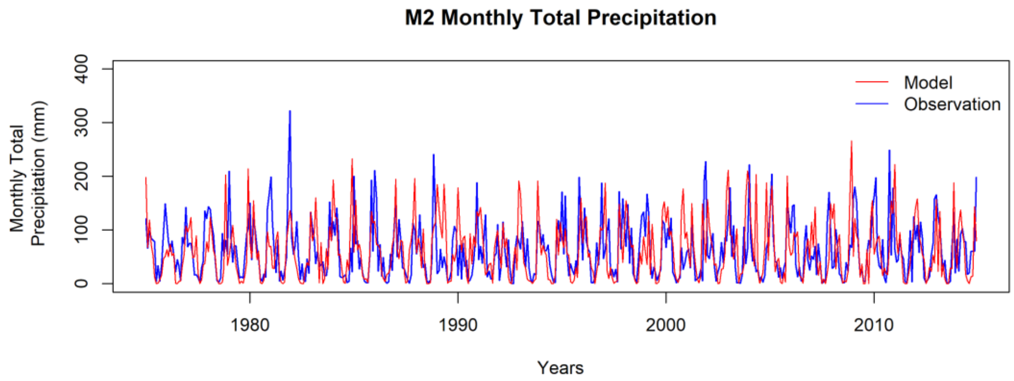


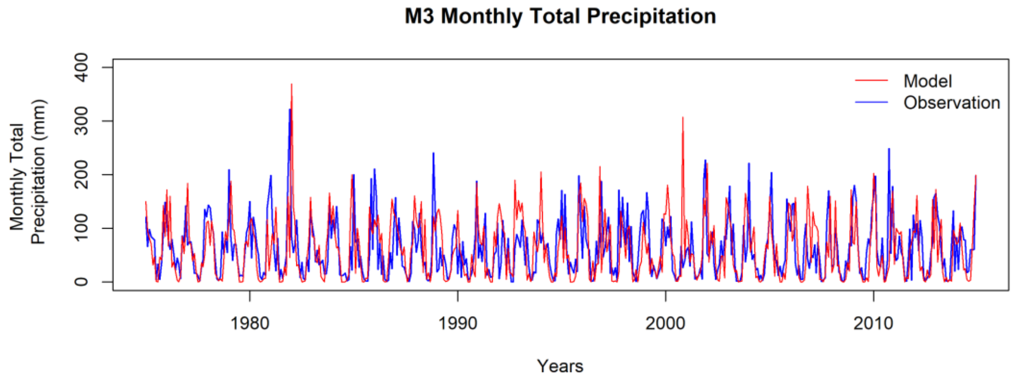


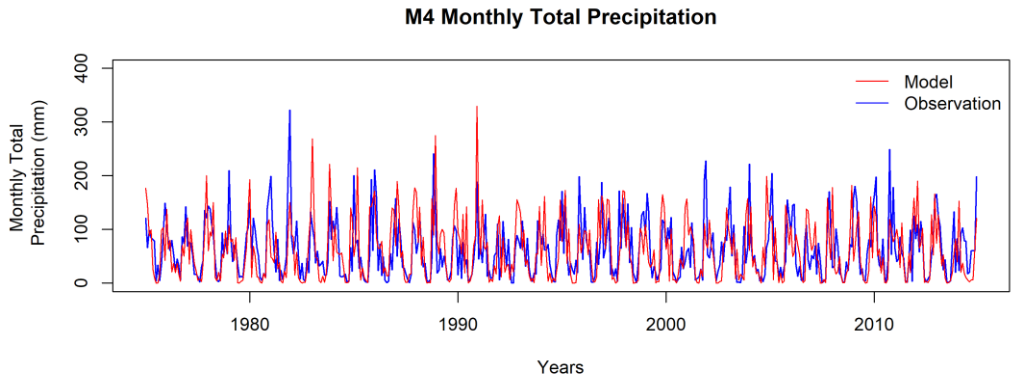
B. Historical Period Individual Model Plots

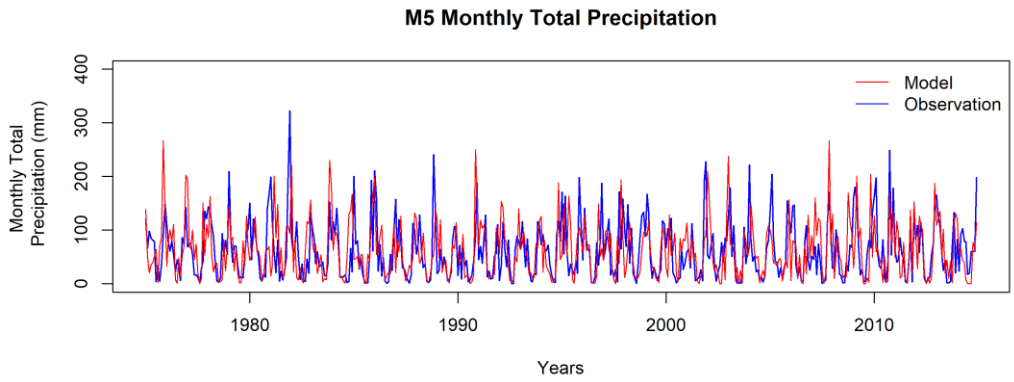
G03 Subbasin Monthly Total Precipitation

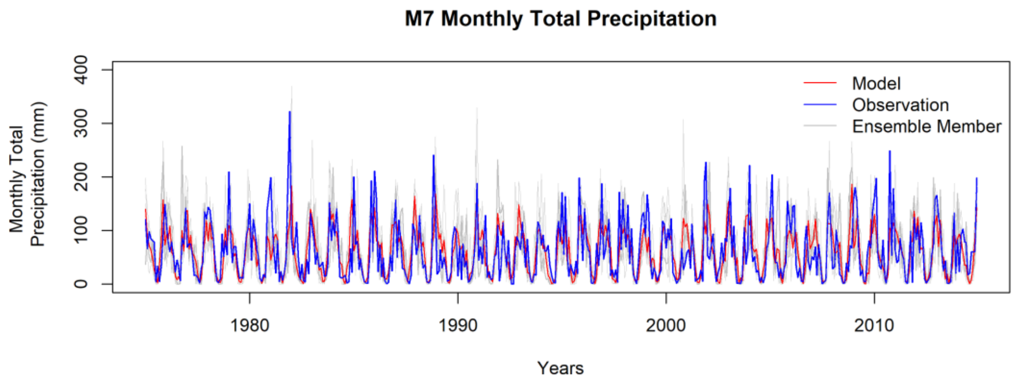


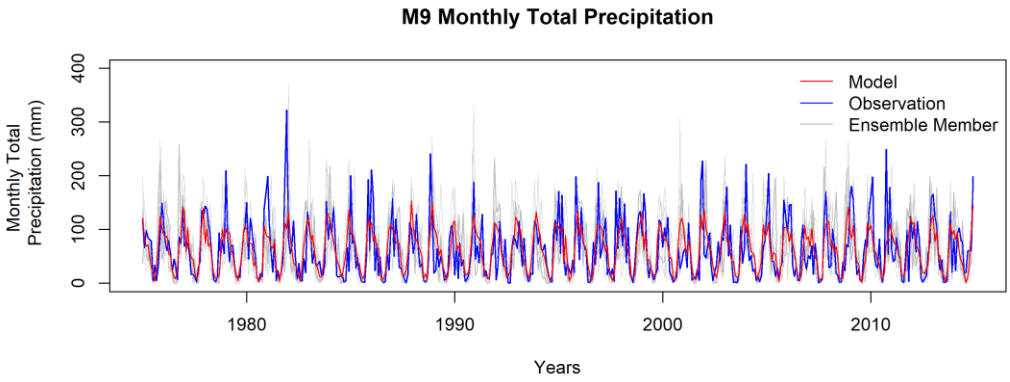


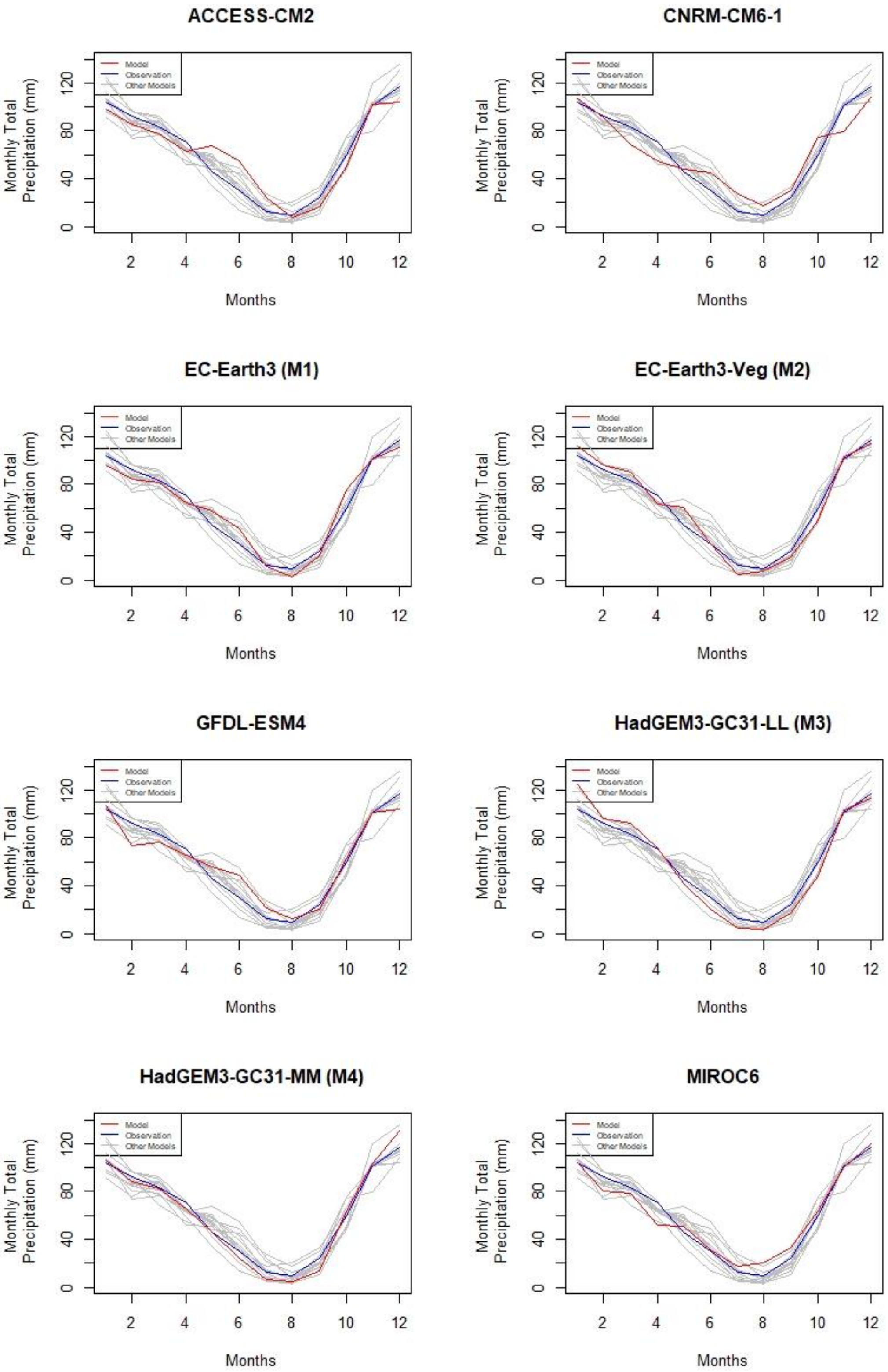



M4 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
Model
Observation
1980
1990
2000
2010
Years

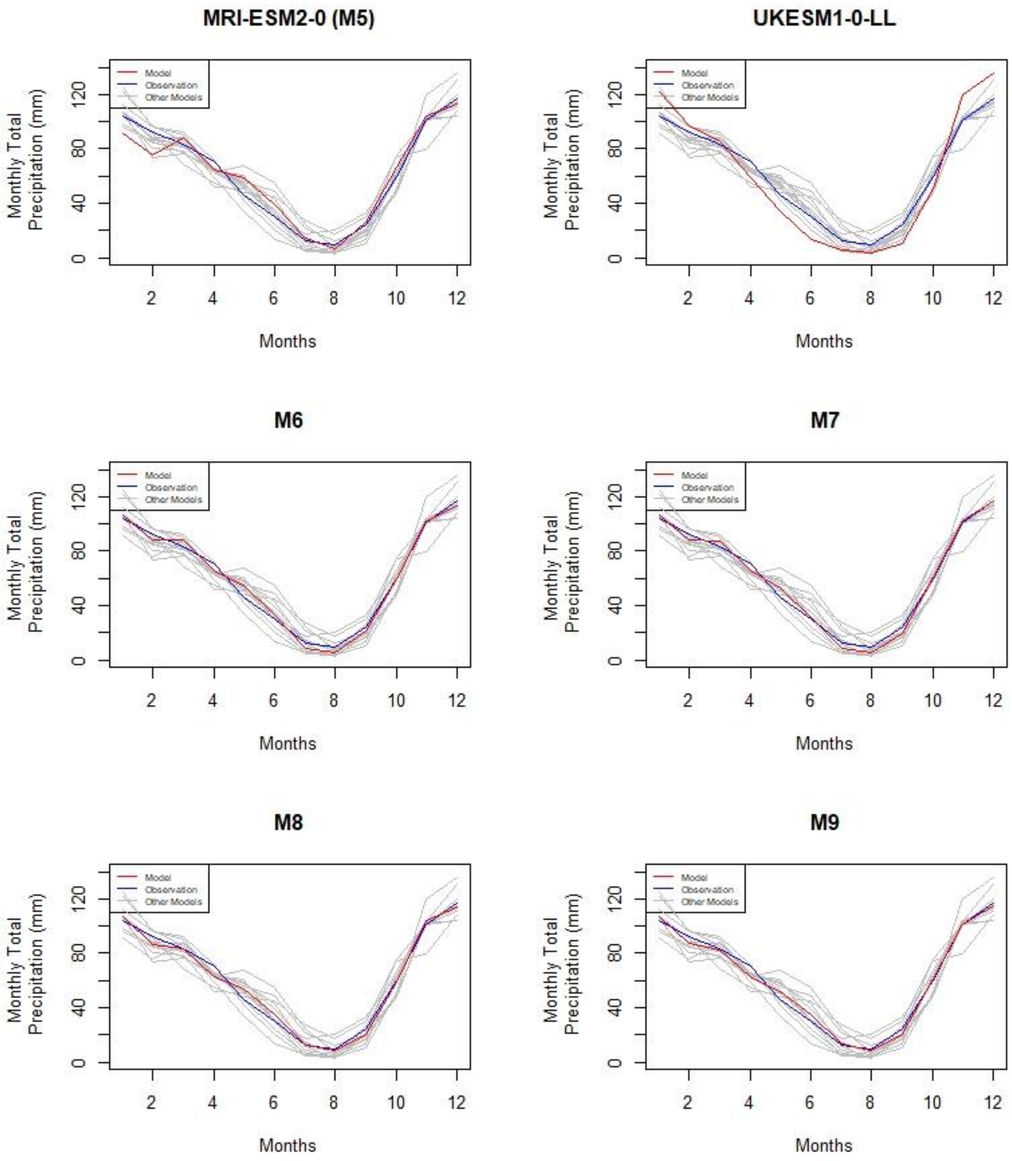

M5 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
Model
Observation
1980
1990
2000
2010
Years


M7 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
Model
Observation
Ensemble Member
1980
1990
2000
2010
Years

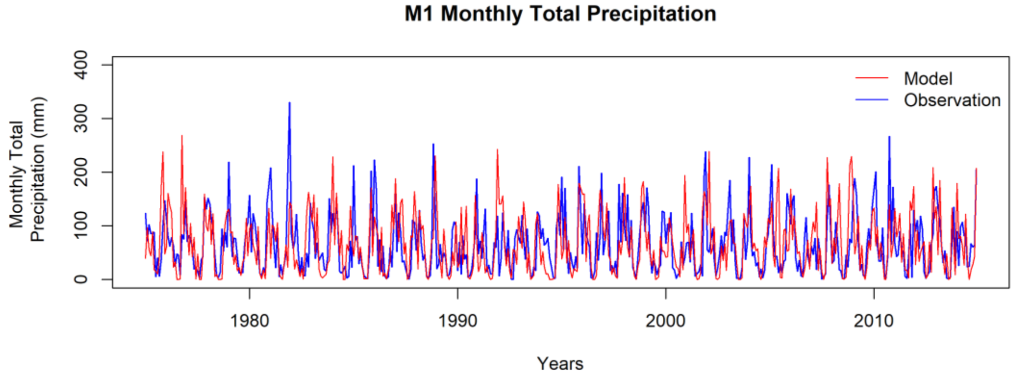

M9 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

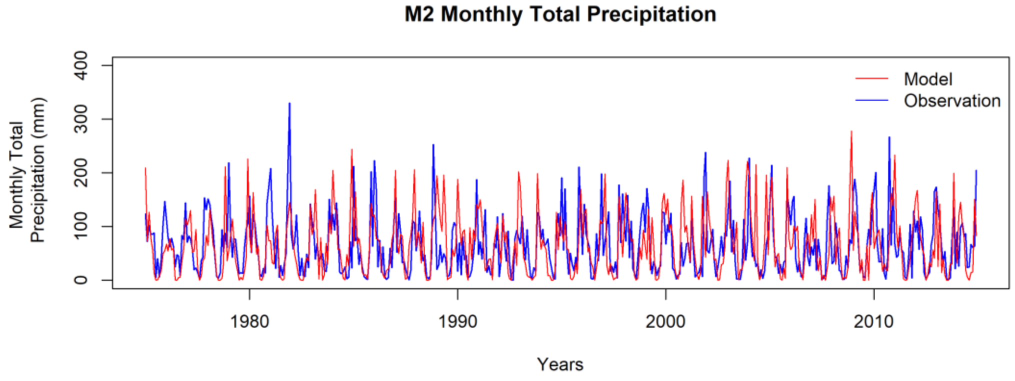


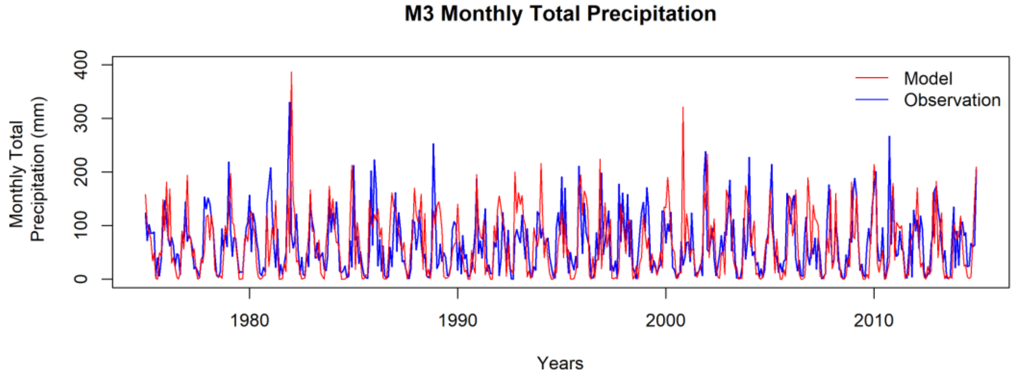
ACCESS-CM2
CNRM-CM6-1
EC-Earth3 (M1)
EC-Earth3-Veg (M2)
GFDL-ESM4
HadGEM3-GC31-LL (M3)
HadGEM3-GC31-MM (M4)
MIROC6
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months
0
40
80
120
2
4
6
8
10
12

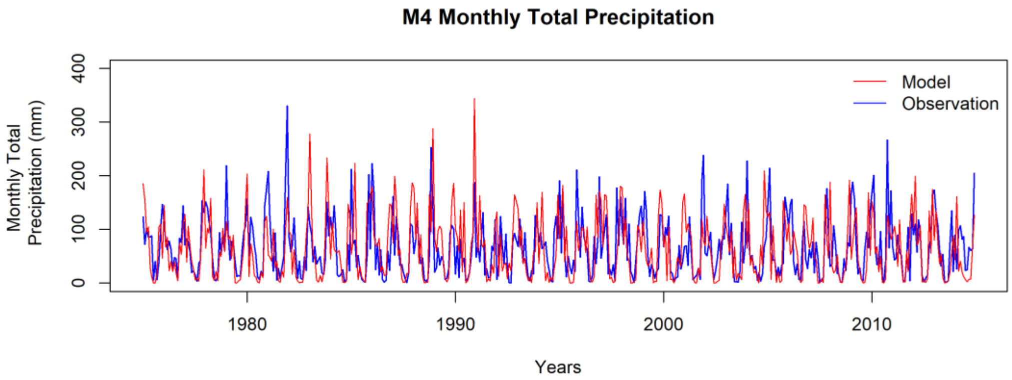

MRI-ESM2-0 (M5)
UKESM1-0-LL
M6
M7
M8
M9
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months

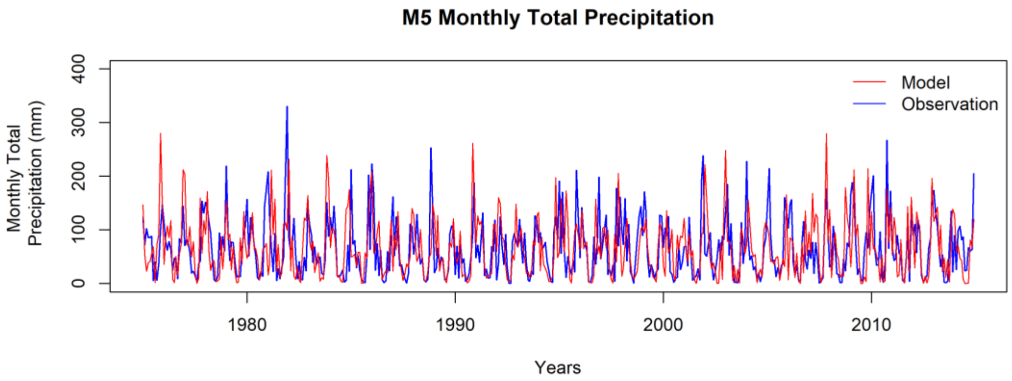
G12 Subbasin Monthly Total Precipitation

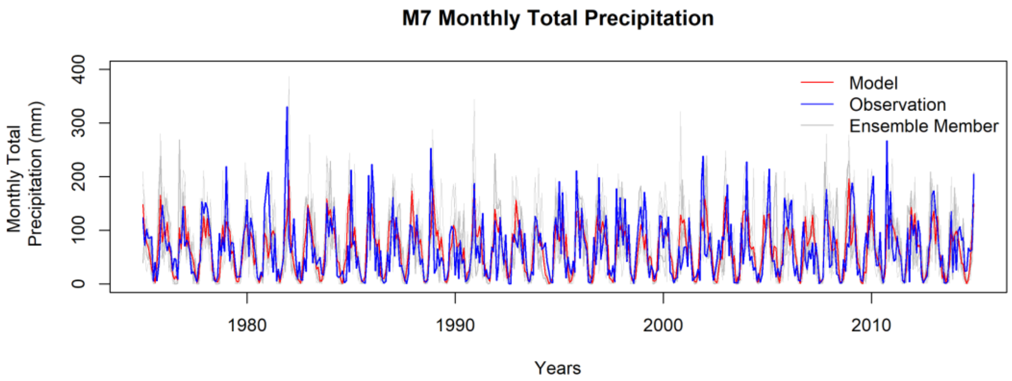


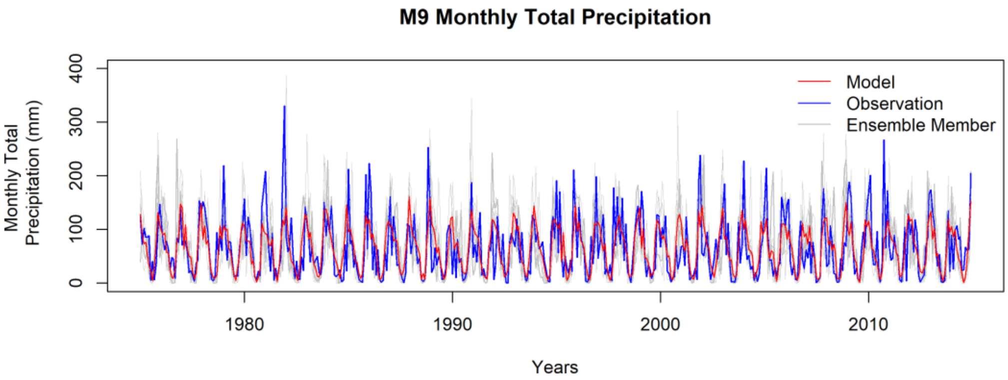


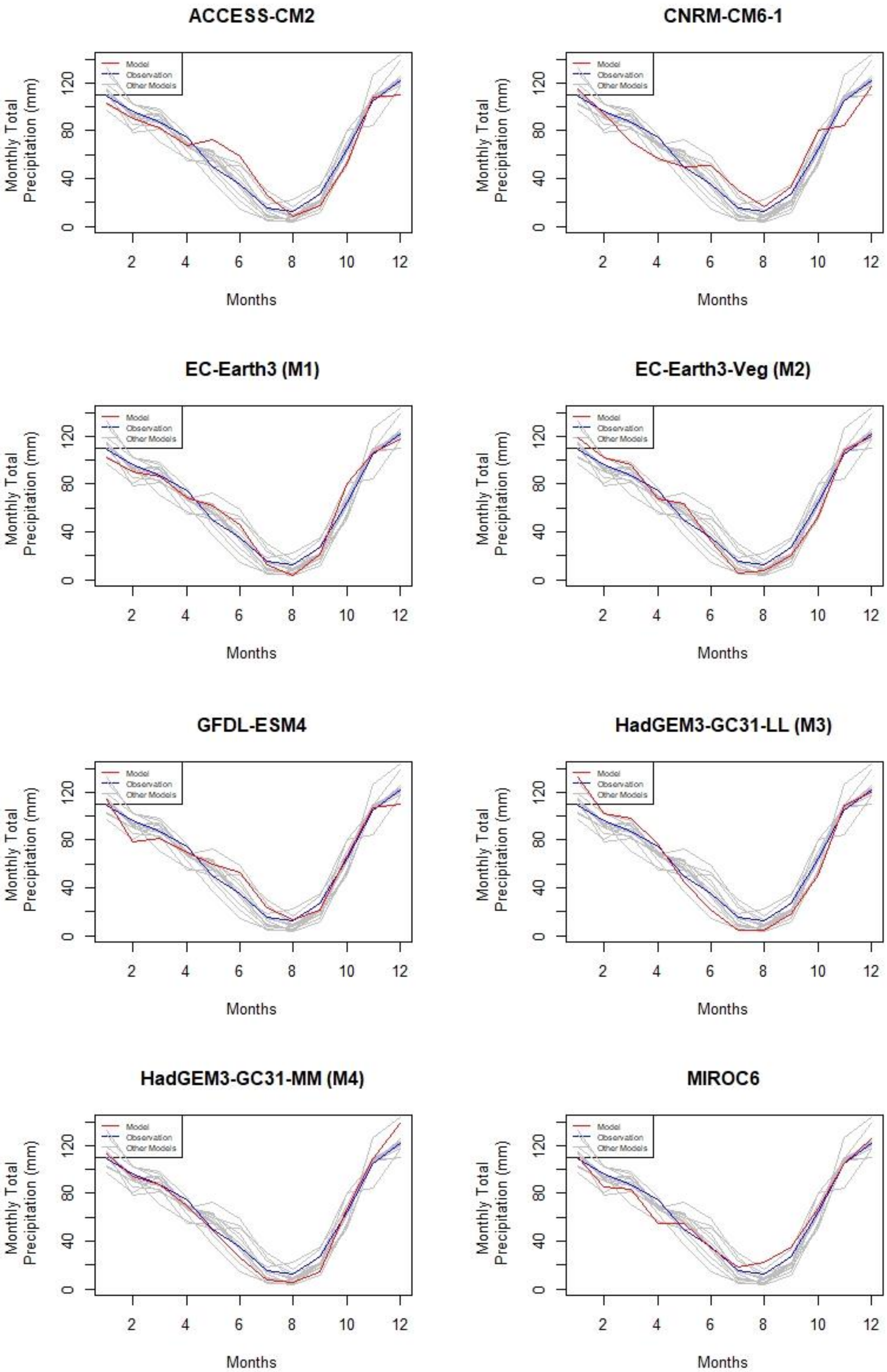


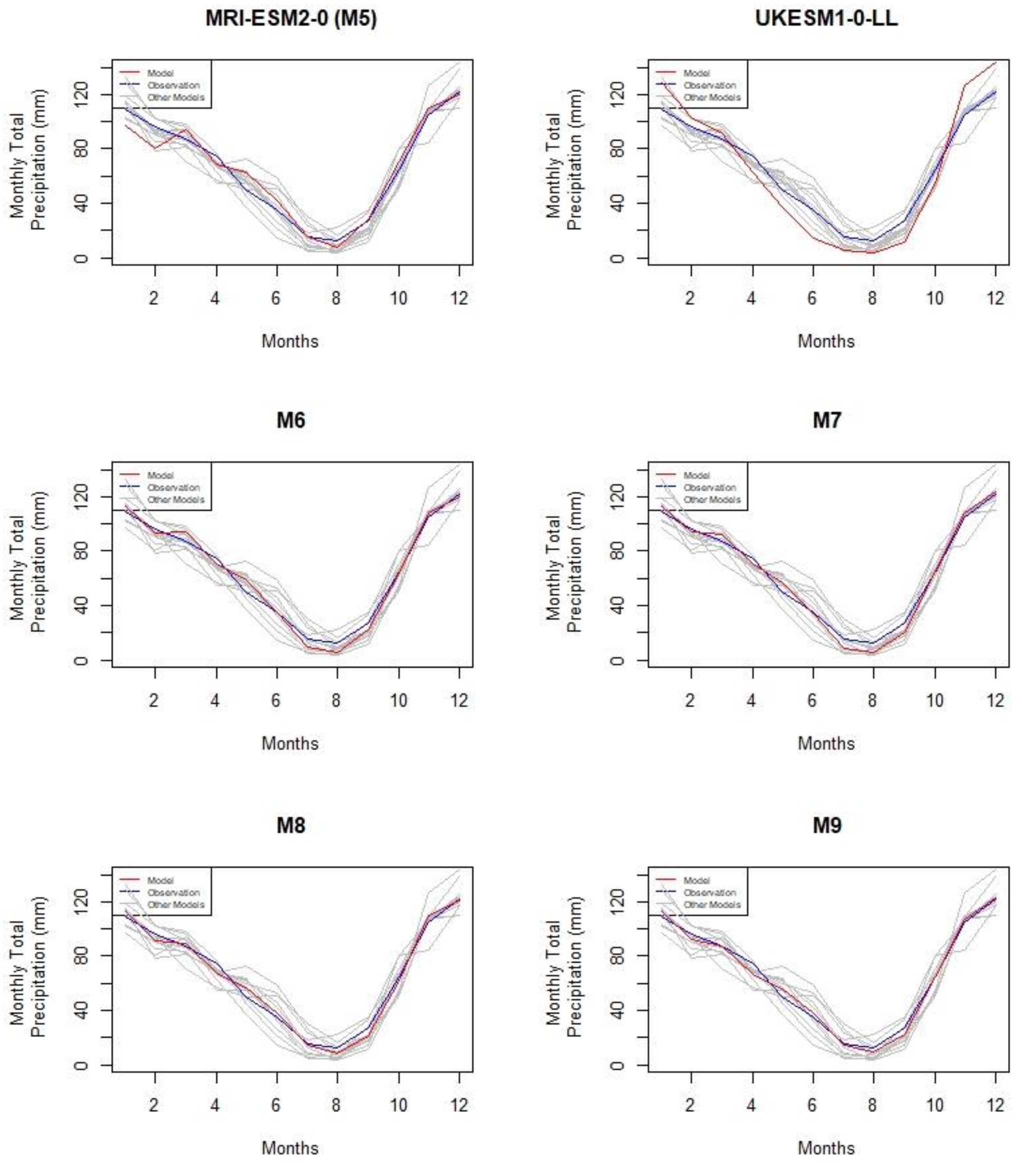

M4 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
Model
Observation
1980
1990
2000
2010
Years


M5 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
Model
Observation
1980
1990
2000
2010
Years

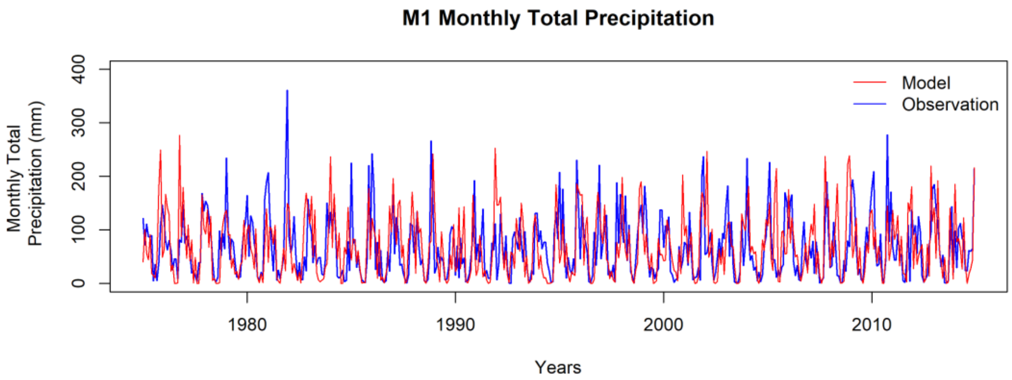

M7 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
Model
Observation
Ensemble Member
1980
1990
2000
2010
Years

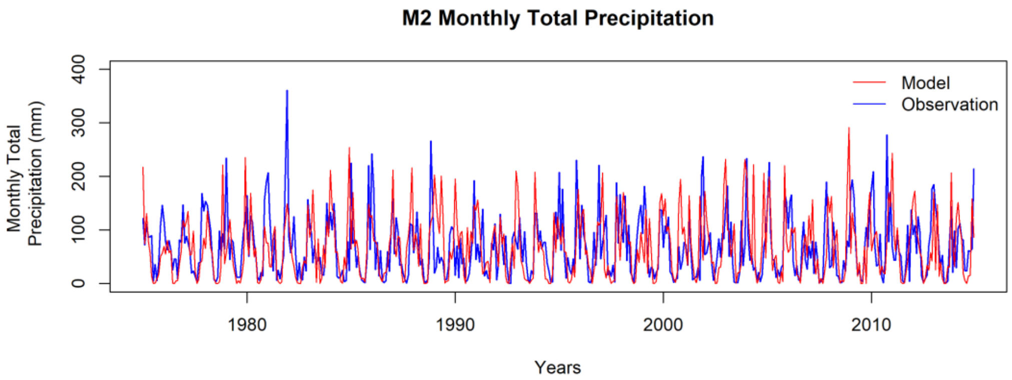

M9 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

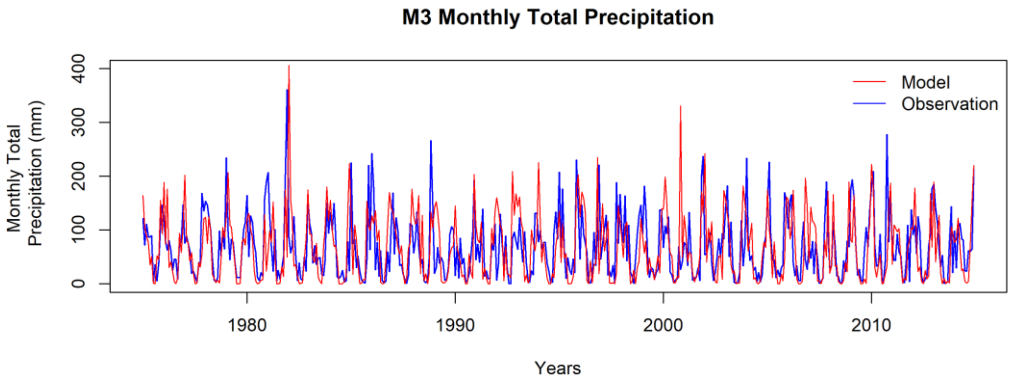

ACCESS-CM2
CNRM-CM6-1
EC-Earth3 (M1)
EC-Earth3-Veg (M2)
GFDL-ESM4
HadGEM3-GC31-LL (M3)
HadGEM3-GC31-MM (M4)
MIROC6
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months

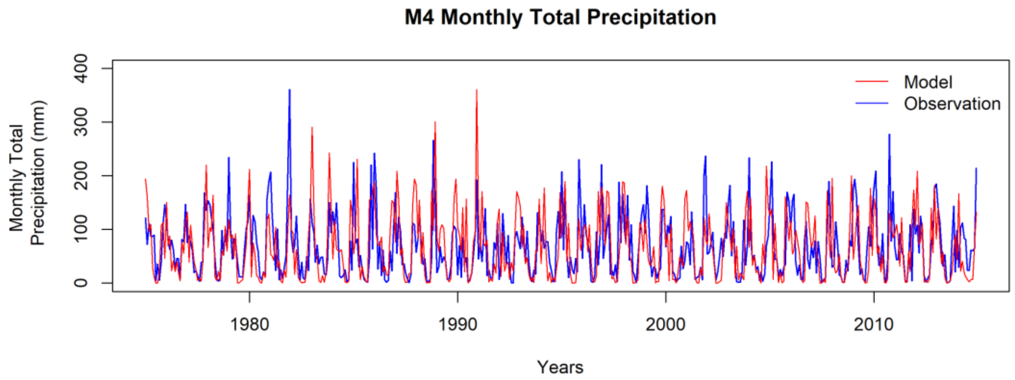

MRI-ESM2-0 (M5)
UKESM1-0-LL
M6
M7
M8
M9
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months
0
40
80
120
2
4
6
8
10
12

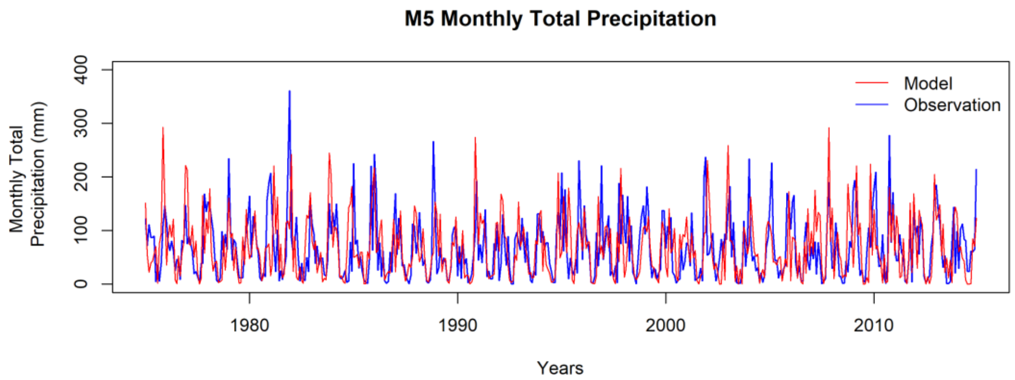
<u>G18 Subbasin Monthly Total Precipitation</u>

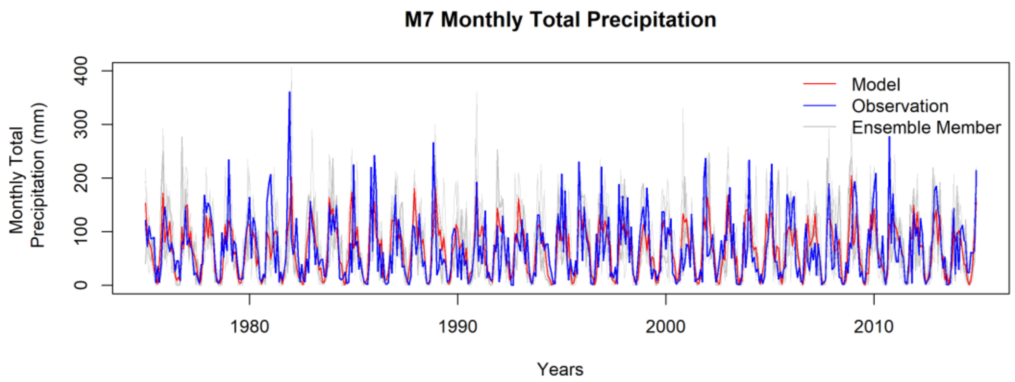


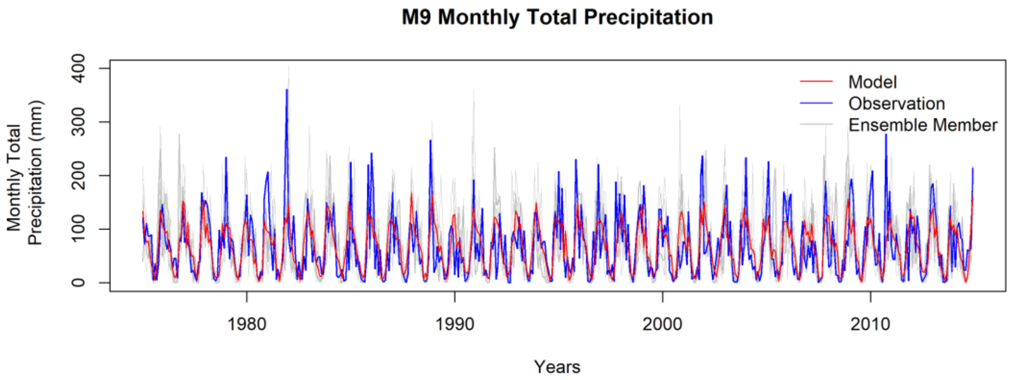


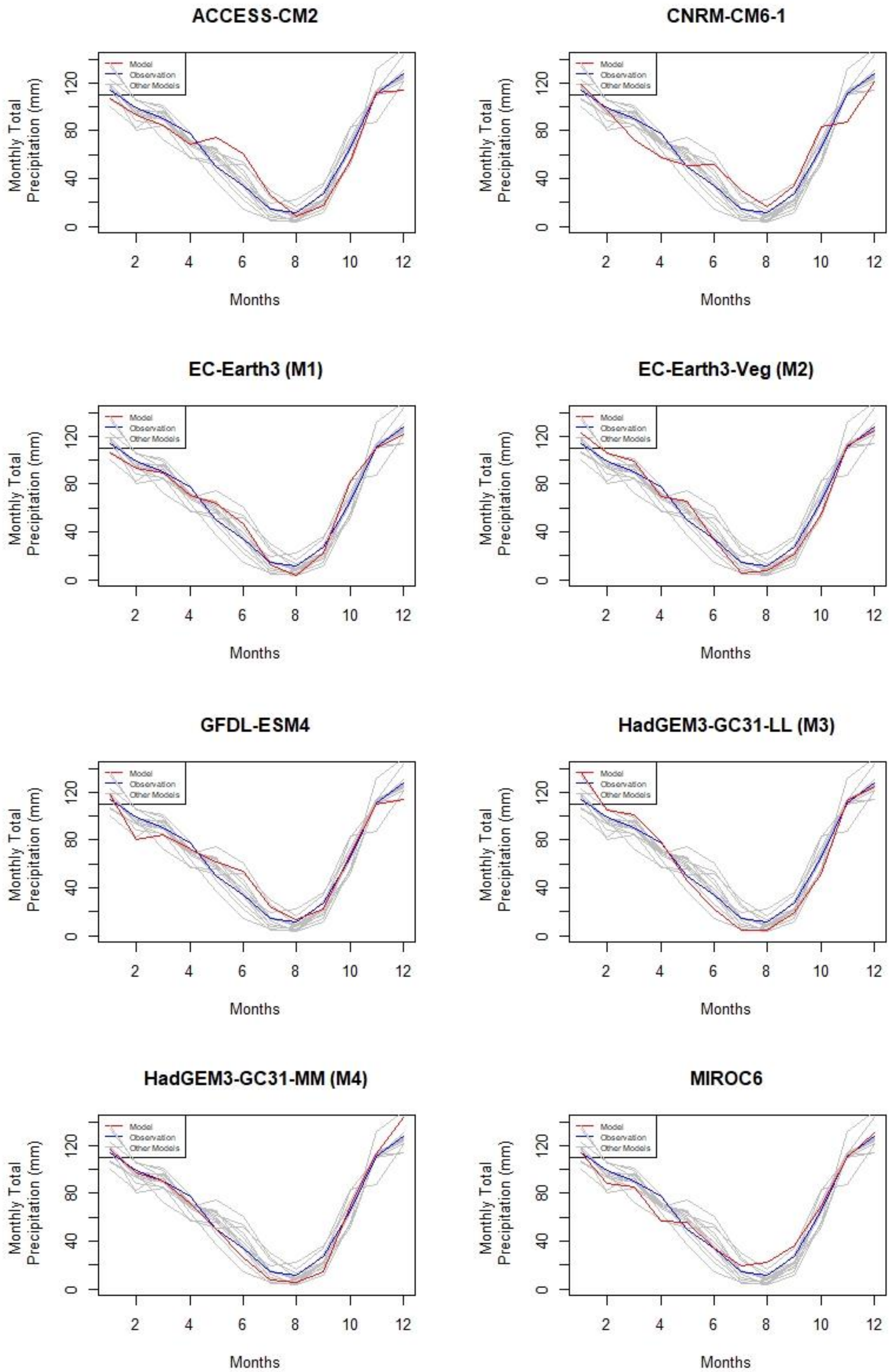


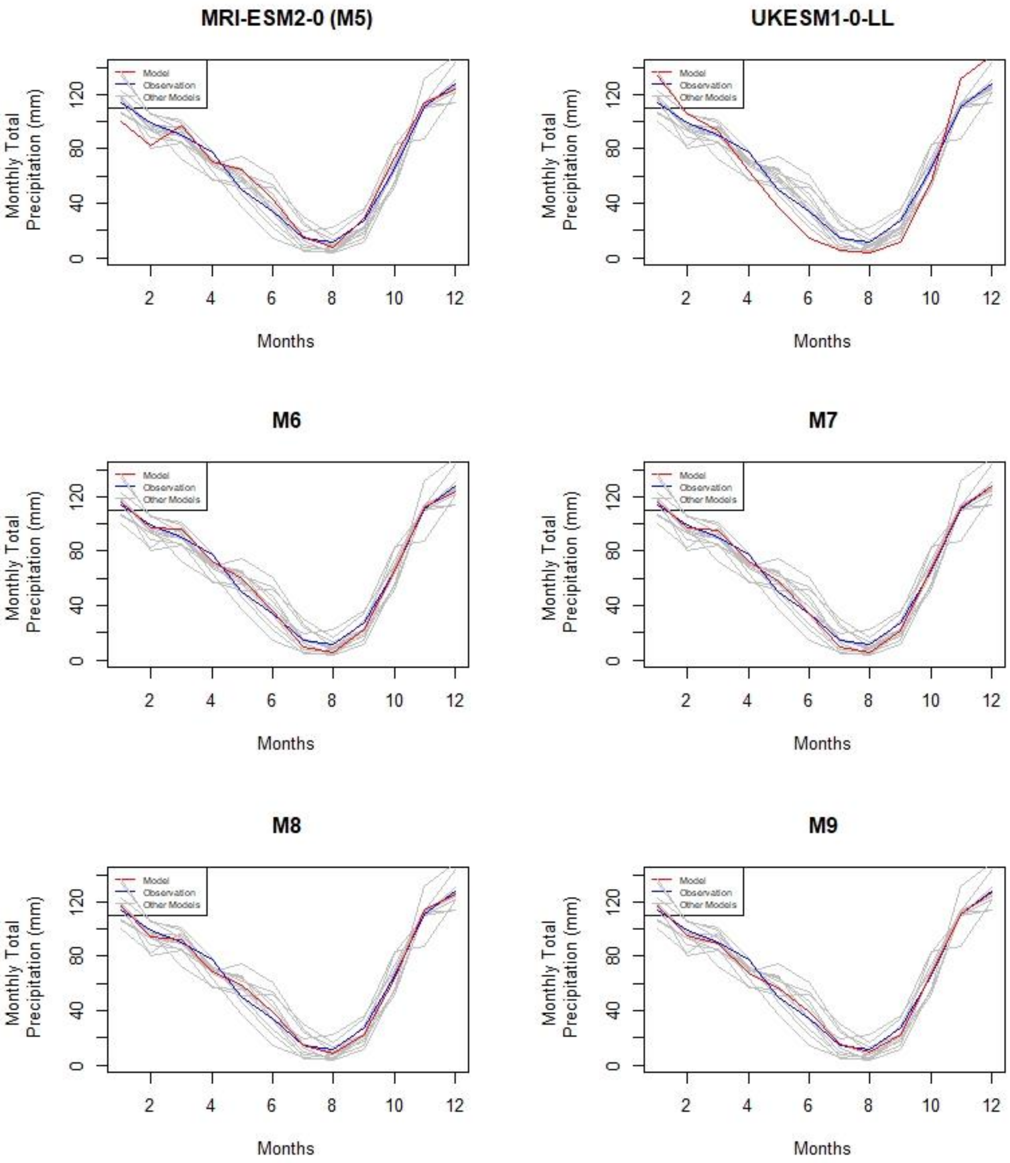

M4 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation


M5 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation

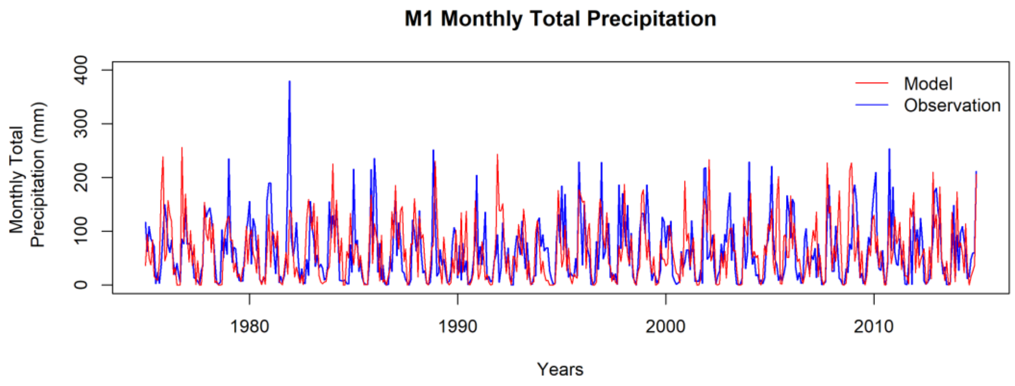

M7 Monthly Total Precipitation
Monthly Total Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

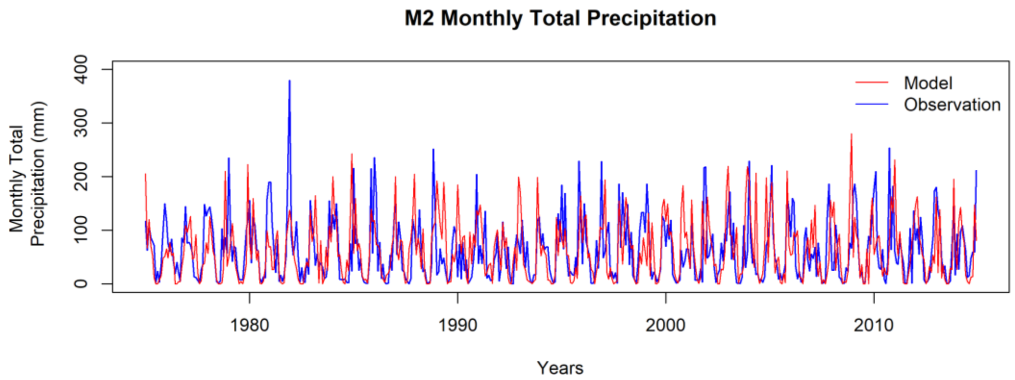

M9 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
Model
Observation
Ensemble Member
1980
1990
2000
2010
Years

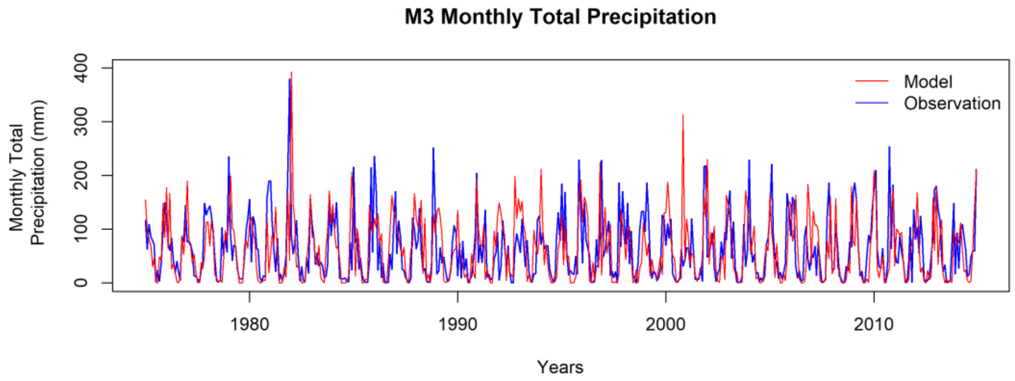

ACCESS-CM2
CNRM-CM6-1
EC-Earth3 (M1)
EC-Earth3-Veg (M2)
GFDL-ESM4
HadGEM3-GC31-LL (M3)
HadGEM3-GC31-MM (M4)
MIROC6
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months
0
40
80
120
2
4
6
8
10
12

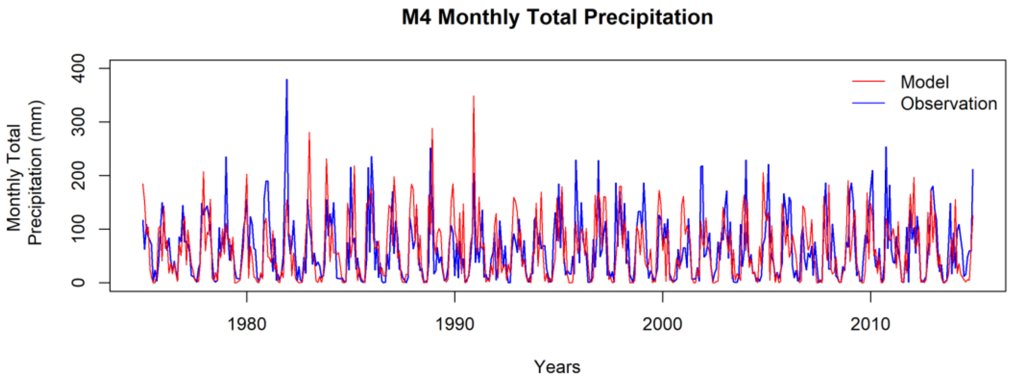

MRI-ESM2-0 (M5)
UKESM1-0-LL
M6
M7
M8
M9
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months
0
40
80
120
2
4
6
8
10
12

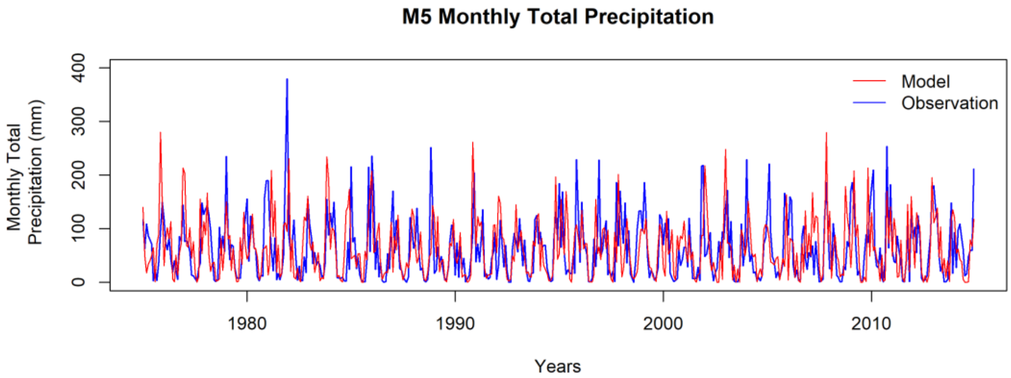
N14 Subbasin Monthly Total Precipitation

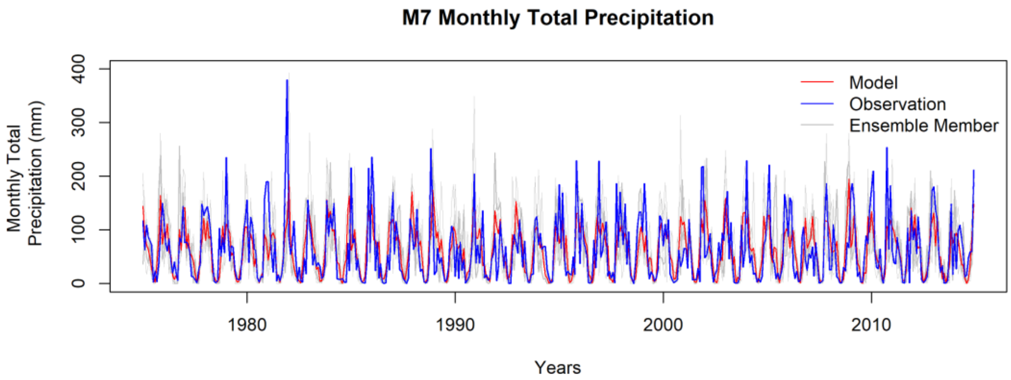


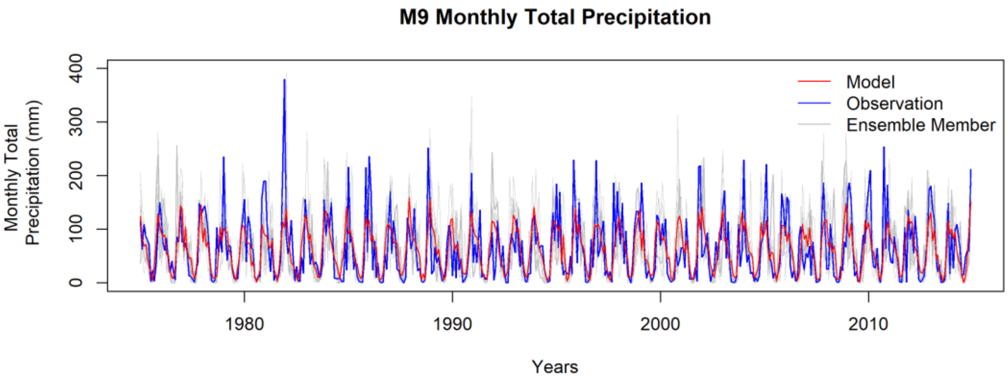




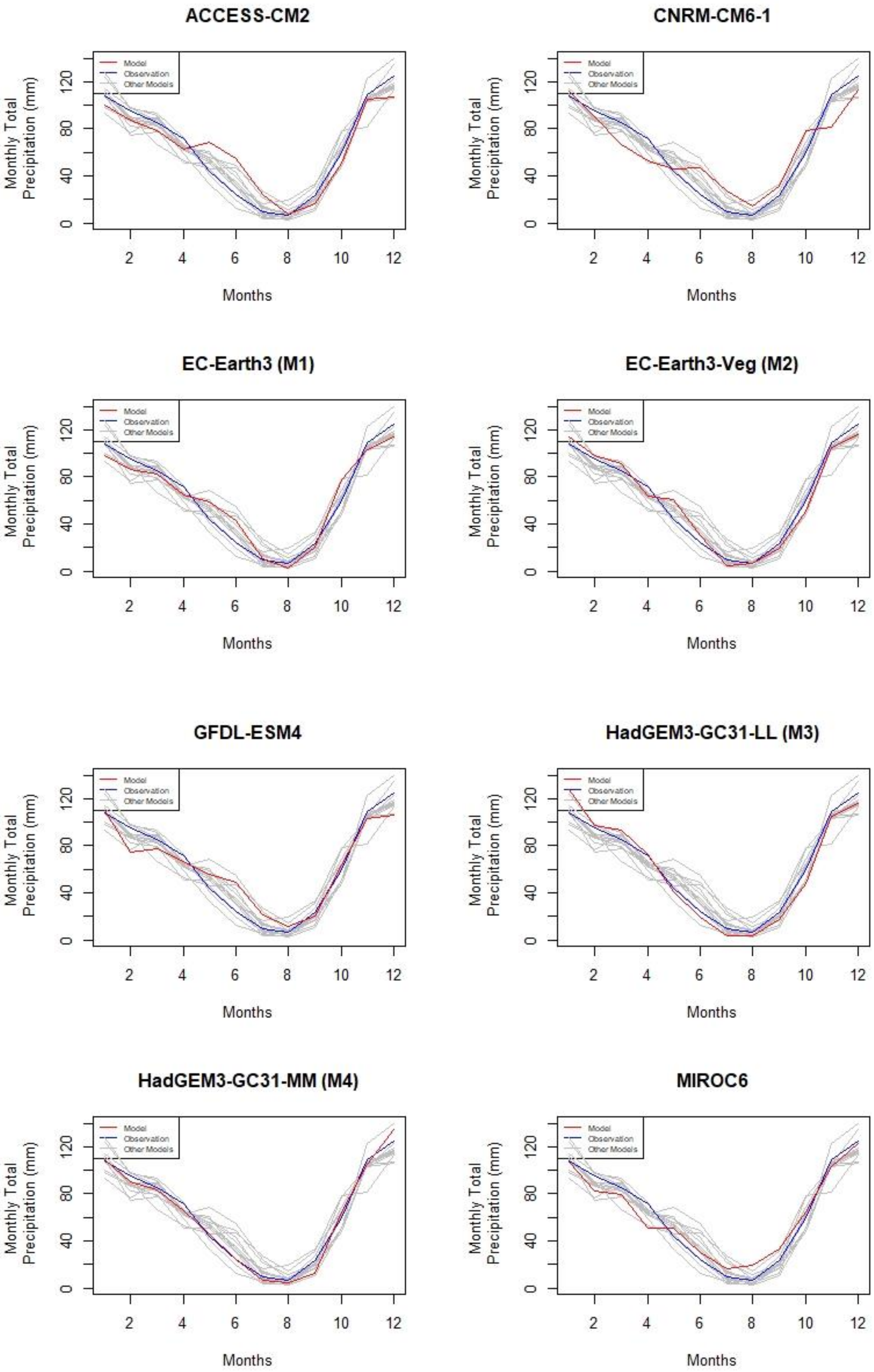

M4 Monthly Total Precipitation
Model
Observation
Monthly Total Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years

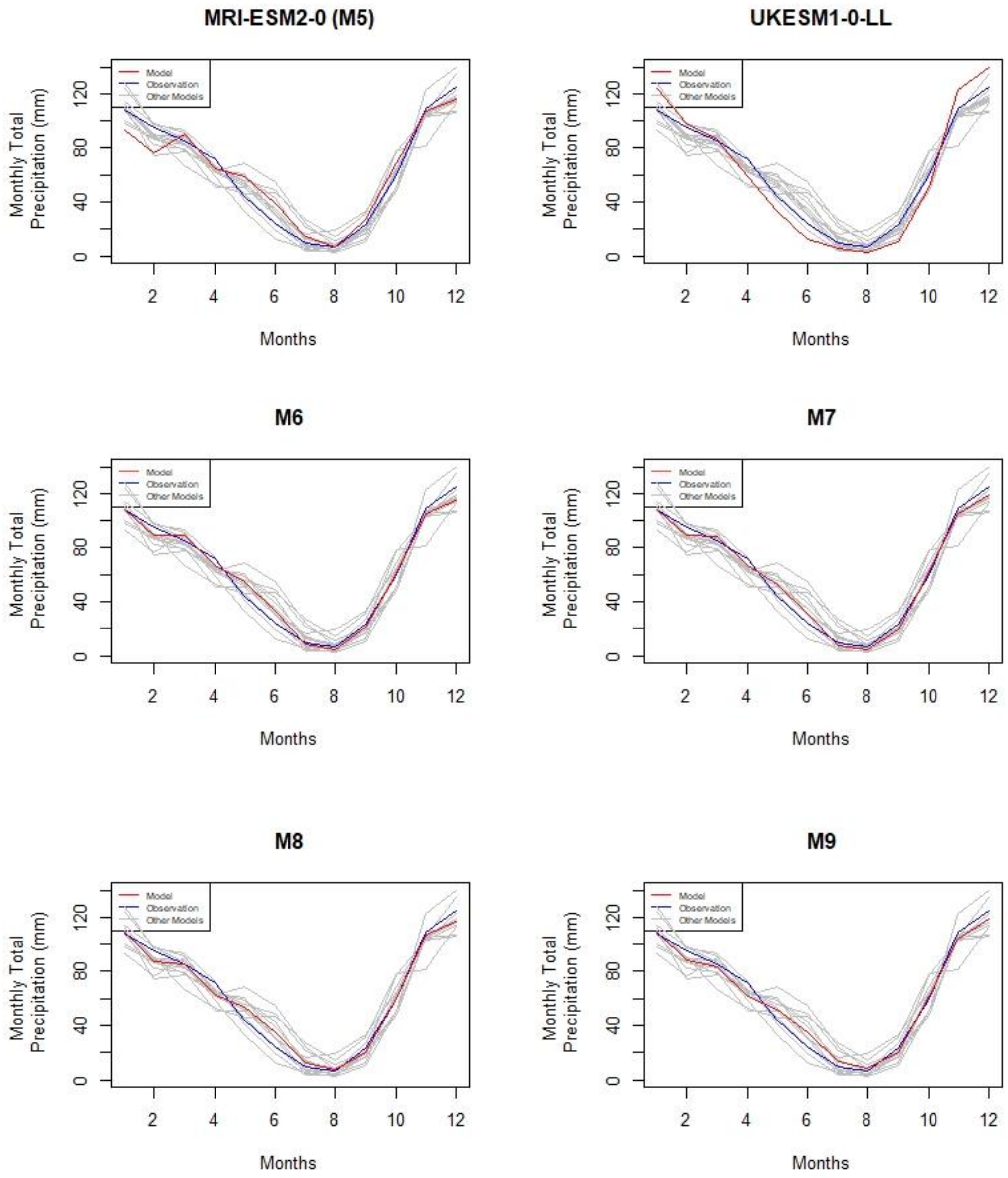

M5 Monthly Total Precipitation
Model
Observation
Monthly Total Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years


M7 Monthly Total Precipitation
Model
Observation
Ensemble Member
Monthly Total Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years

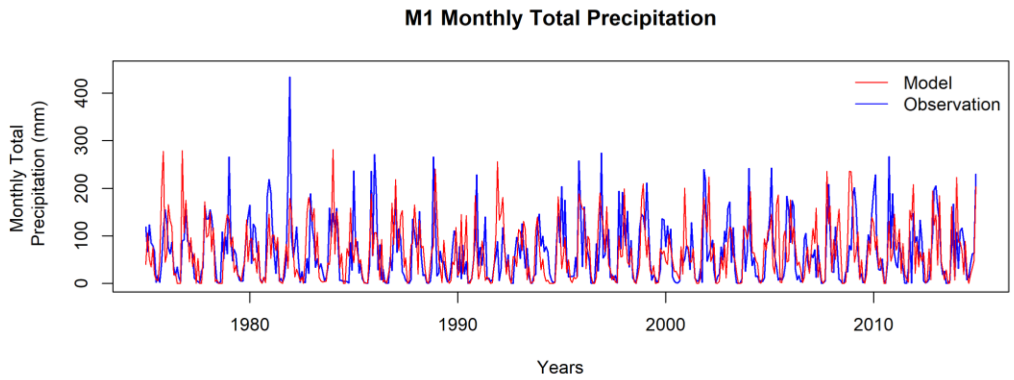


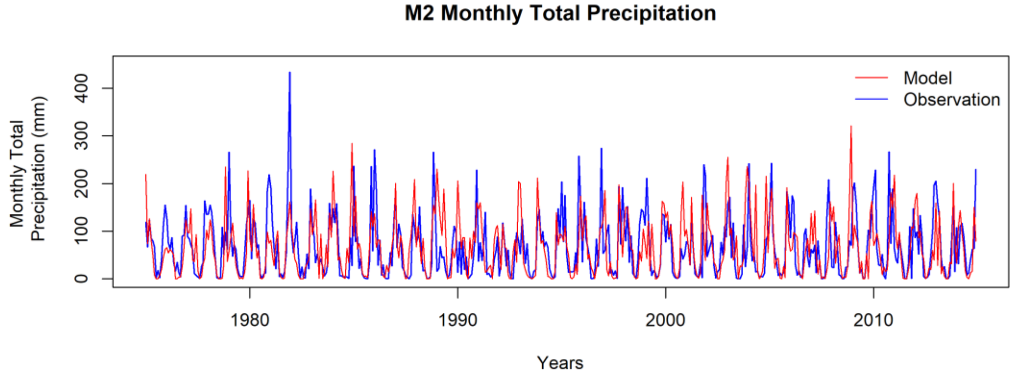
M9 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
Model
Observation
Ensemble Member
1980
1990
2000
2010
Years

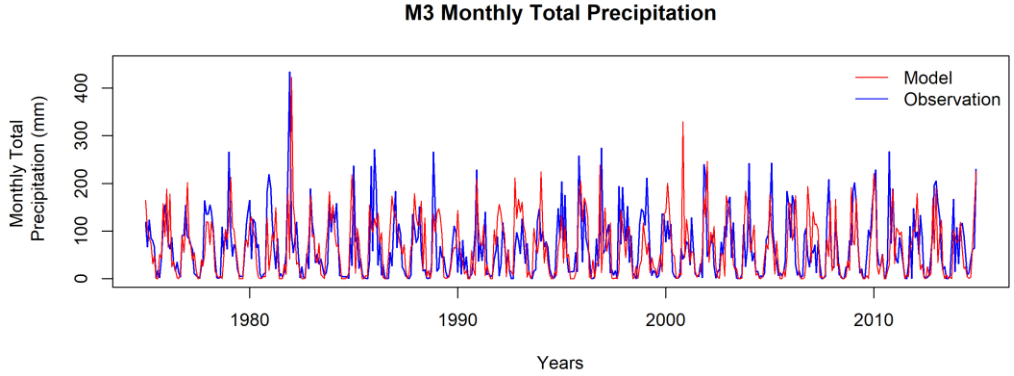

ACCESS-CM2
CNRM-CM6-1
EC-Earth3 (M1)
EC-Earth3-Veg (M2)
GFDL-ESM4
HadGEM3-GC31-LL (M3)
HadGEM3-GC31-MM (M4)
MIROC6
Monthly Total Precipitation (mm)
Months
Model
Observation
Other Models
0
40
80
120
2
4
6
8
10
12

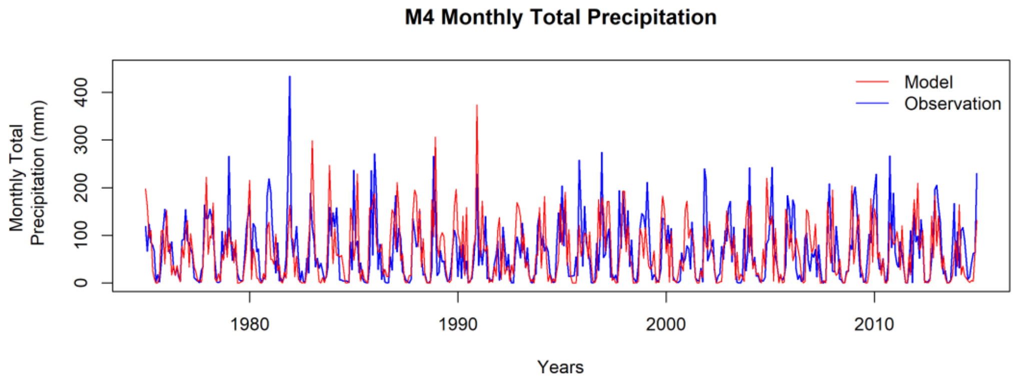

MRI-ESM2-0 (M5)
UKESM1-0-LL
M6
M7
M8
M9
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months
0
40
80
120
2
4
6
8
10
12

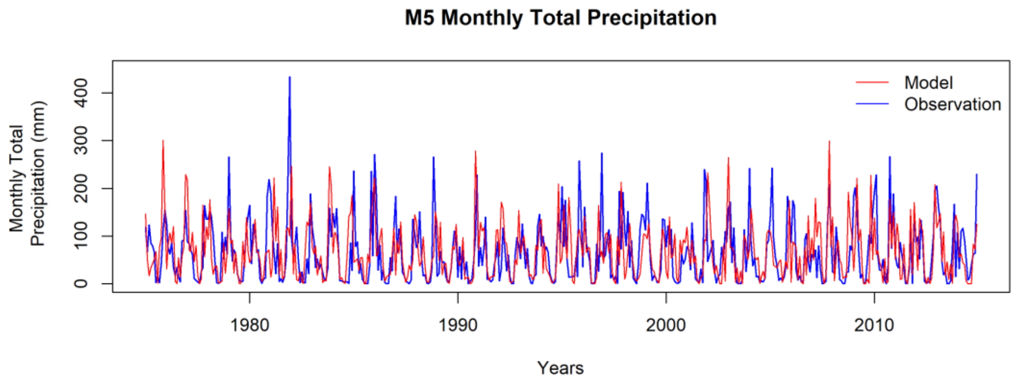
N15 Subbasin Monthly Total Precipitation

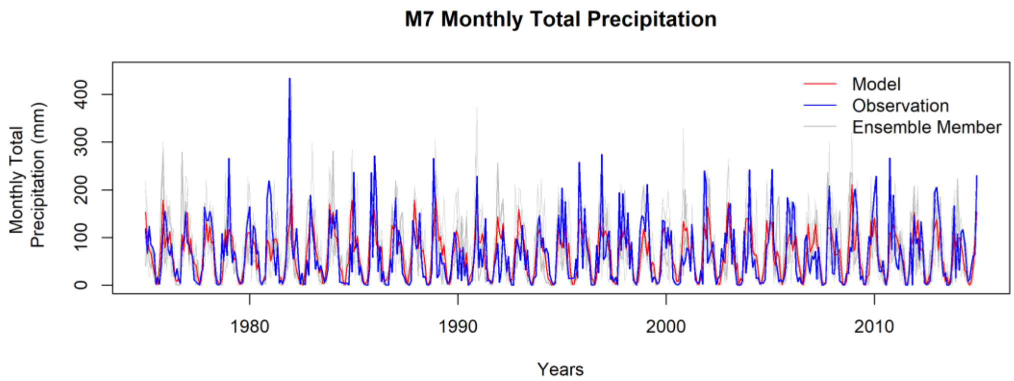


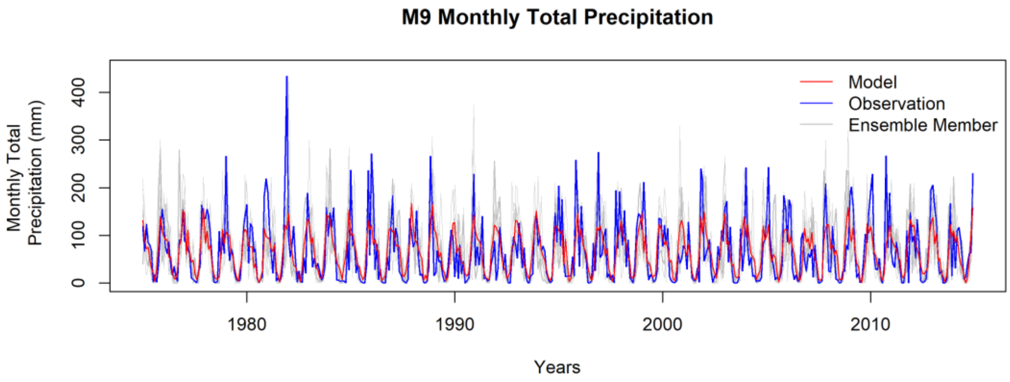


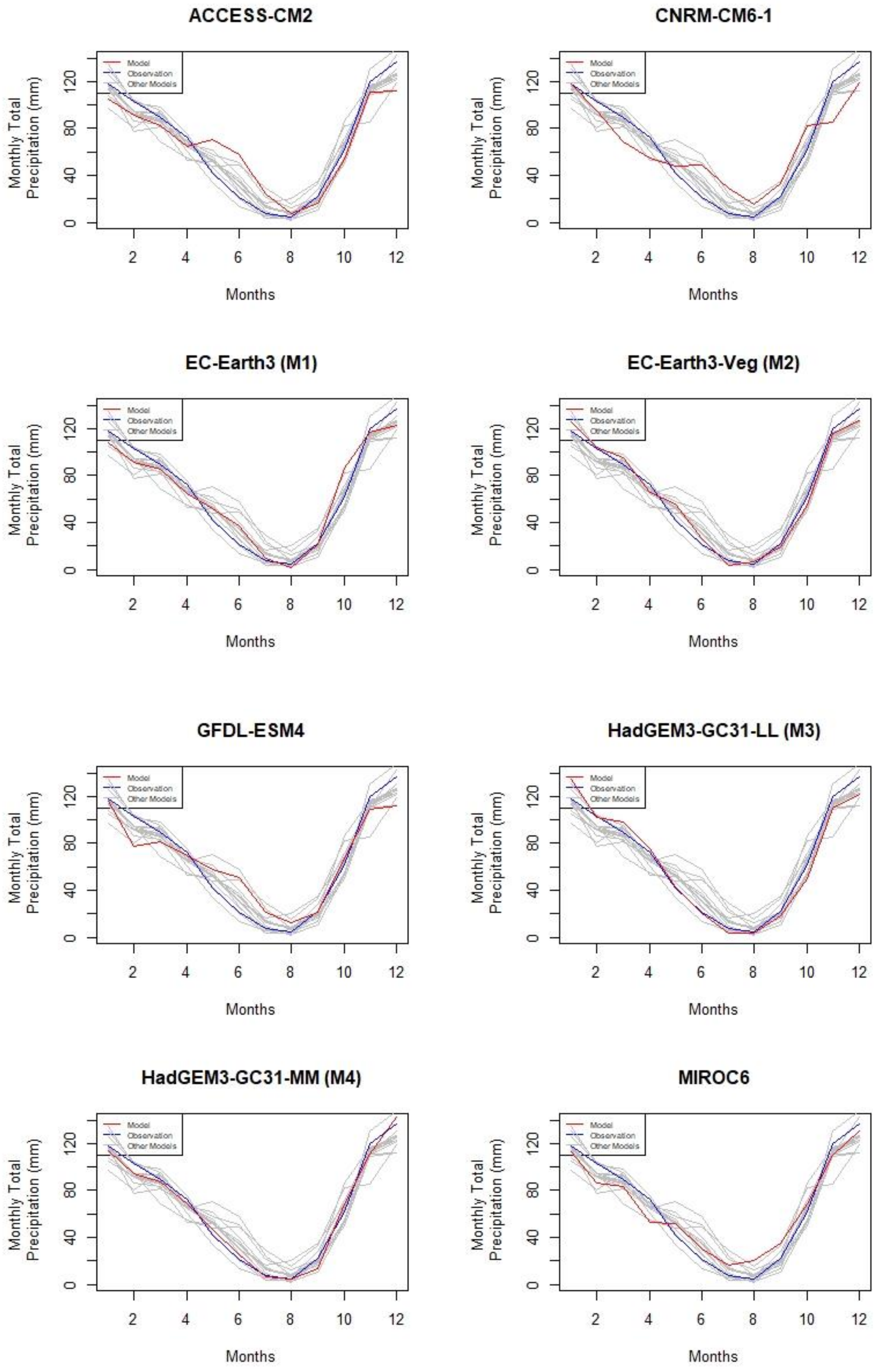


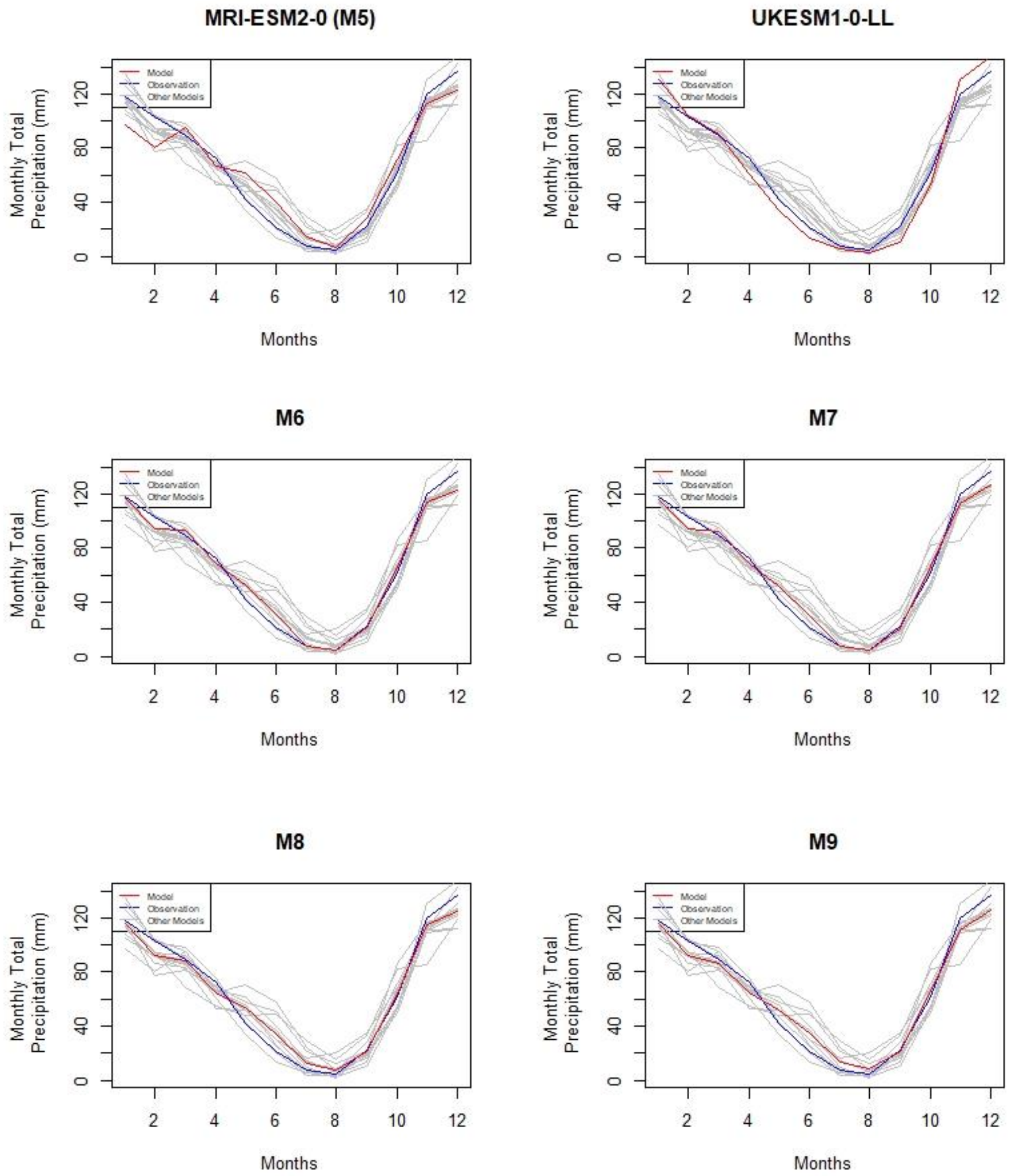

M4 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation


M5 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation

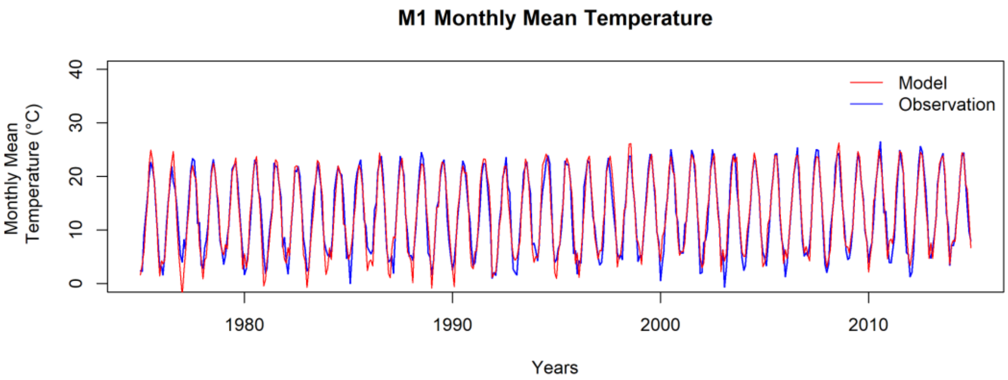

M7 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

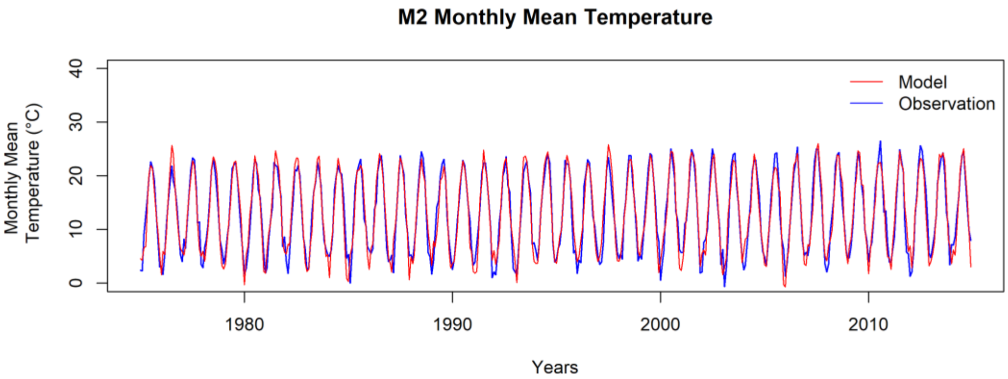

M9 Monthly Total Precipitation
Monthly Total
Precipitation (mm)
0
100
200
300
400
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

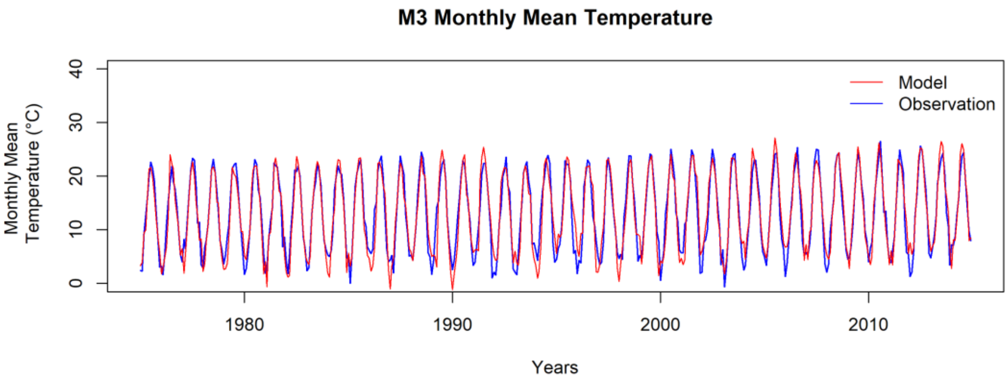

ACCESS-CM2
CNRM-CM6-1
EC-Earth3 (M1)
EC-Earth3-Veg (M2)
GFDL-ESM4
HadGEM3-GC31-LL (M3)
HadGEM3-GC31-MM (M4)
MIROC6
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months

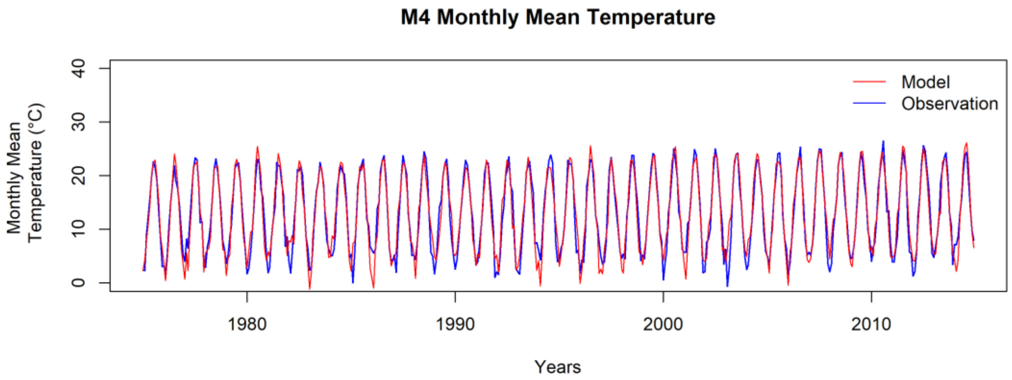

MRI-ESM2-0 (M5)
UKESM1-0-LL
M6
M7
M8
M9
Model
Observation
Other Models
Monthly Total Precipitation (mm)
Months

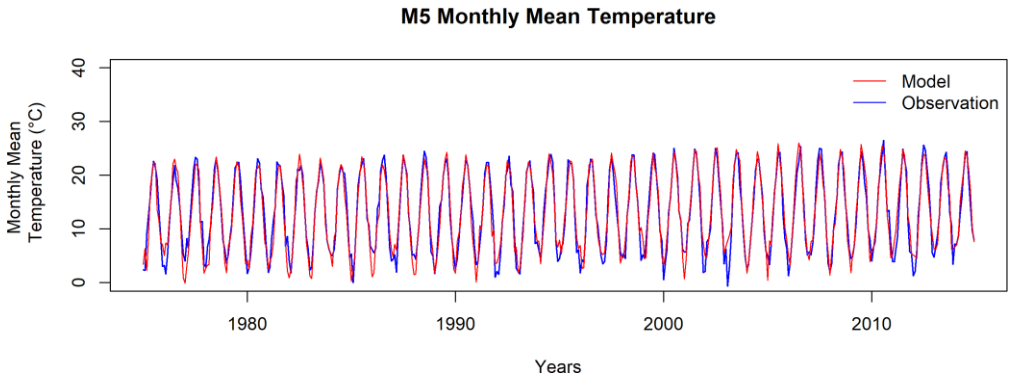
G03 Subbasin Monthly Mean Temperature

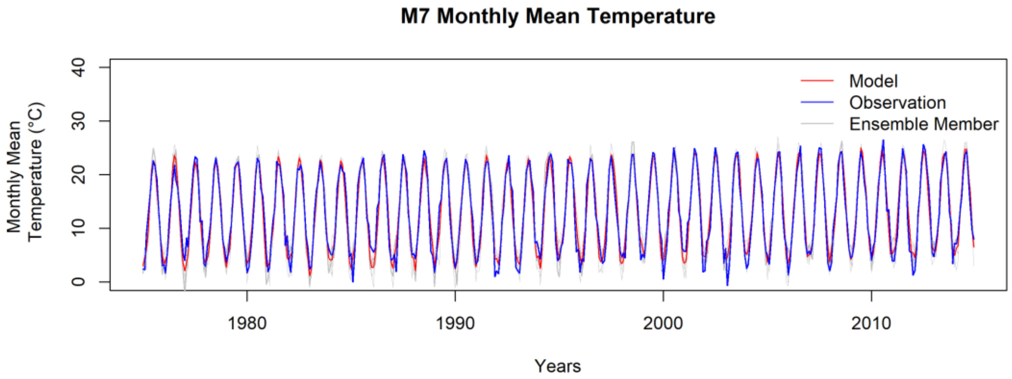


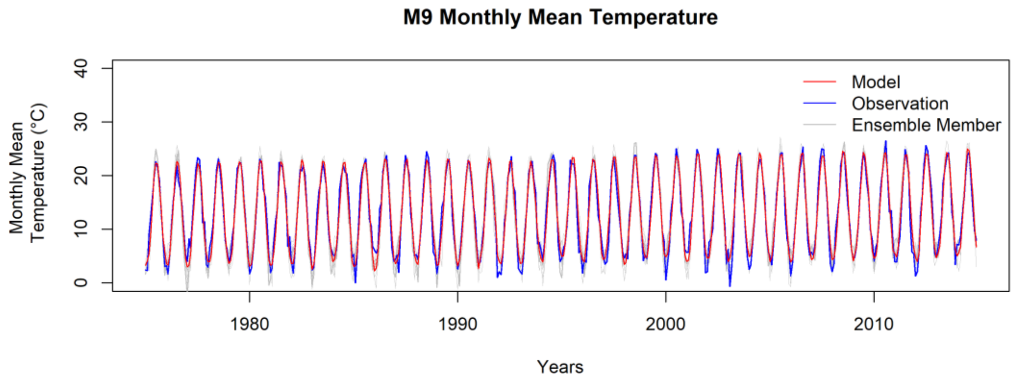




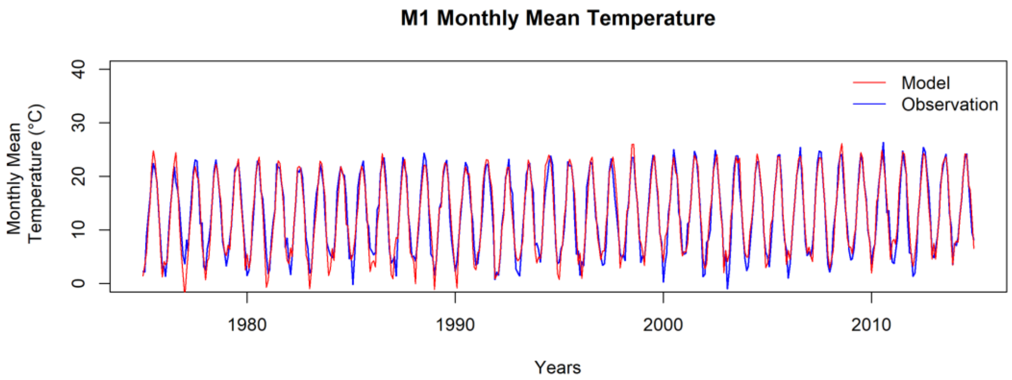

M4 Monthly Mean Temperature
Monthly Mean Temperature (°C)
Model
Observation
Years

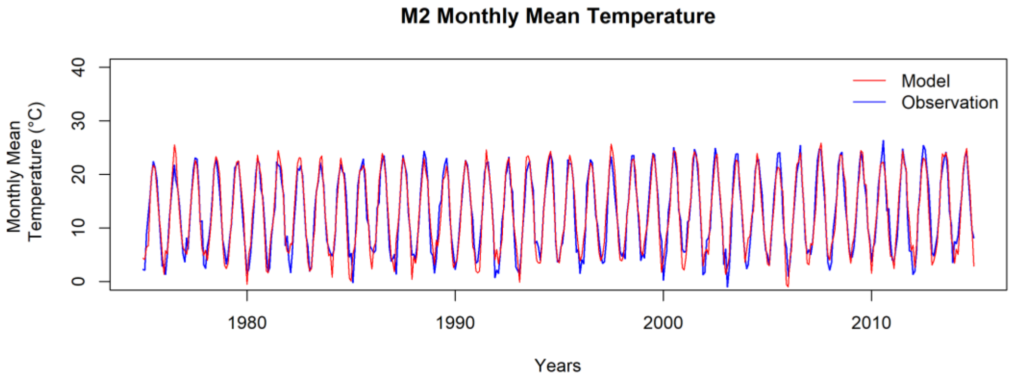

M5 Monthly Mean Temperature
Monthly Mean Temperature (°C)
Model
Observation
Years

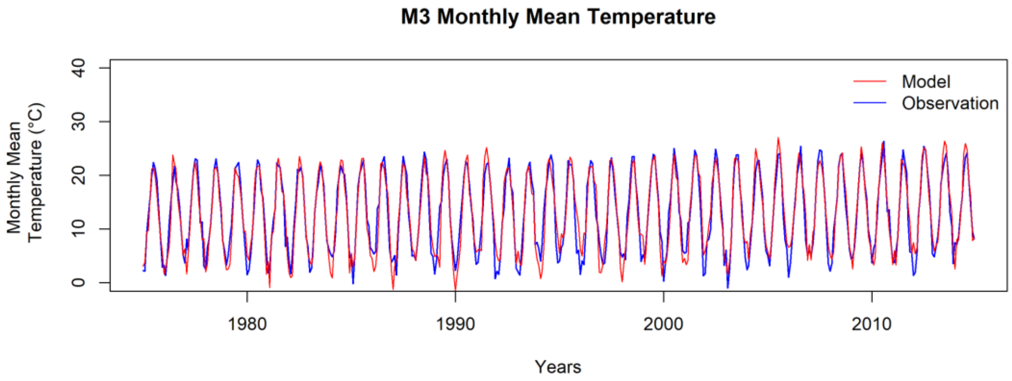

M7 Monthly Mean Temperature
Monthly Mean Temperature (°C)
Model
Observation
Ensemble Member
Years

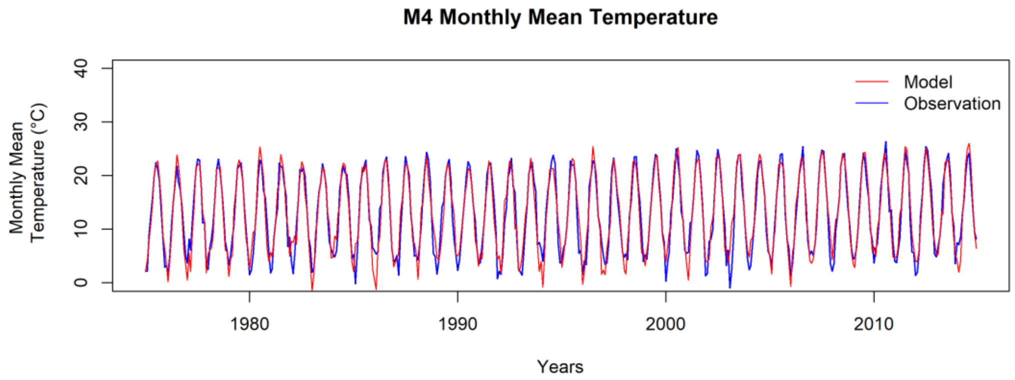

M9 Monthly Mean Temperature
Monthly Mean
Temperature (°C)
0
10
20
30
40
Model
Observation
Ensemble Member
1980
1990
2000
2010
Years

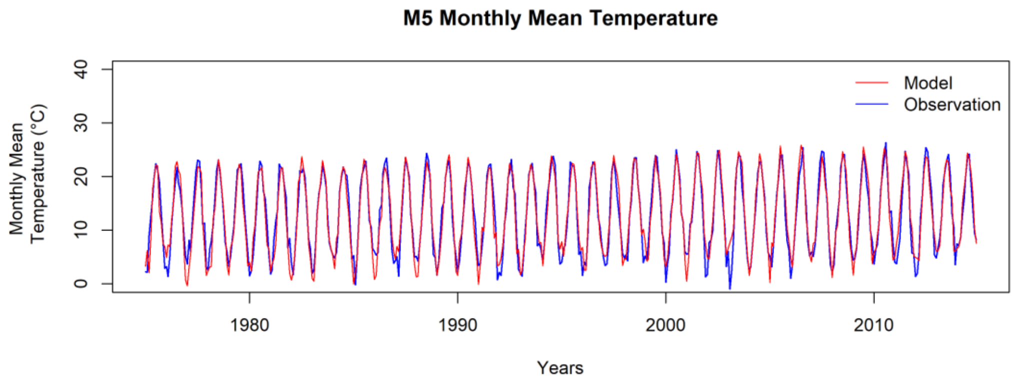
G12 Subbasin Monthly Mean Temperature

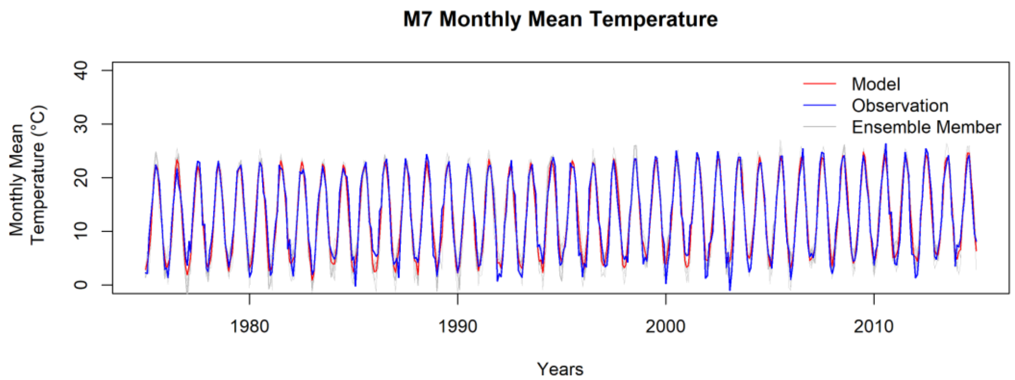


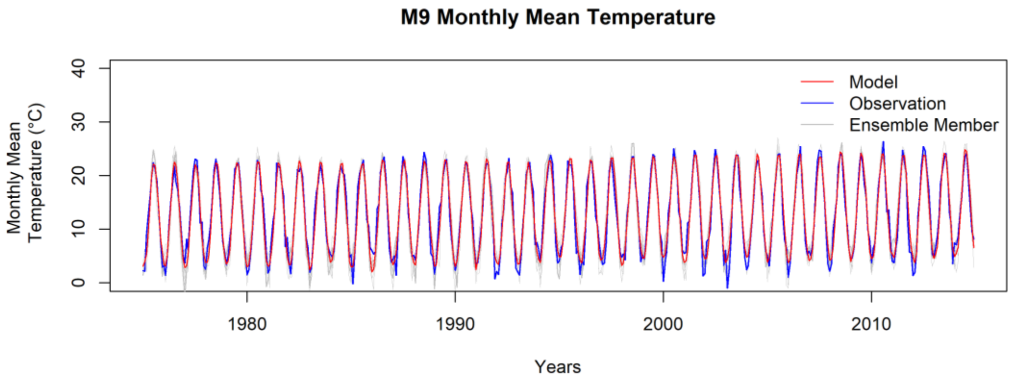




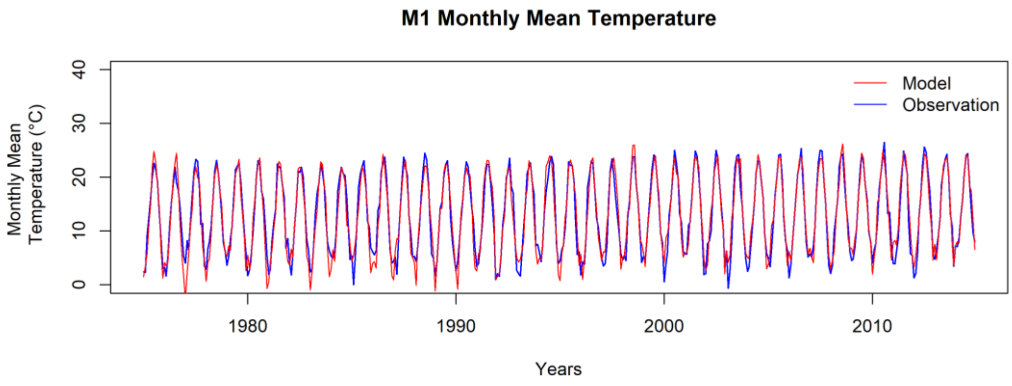

M4 Monthly Mean Temperature
Model
Observation
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years

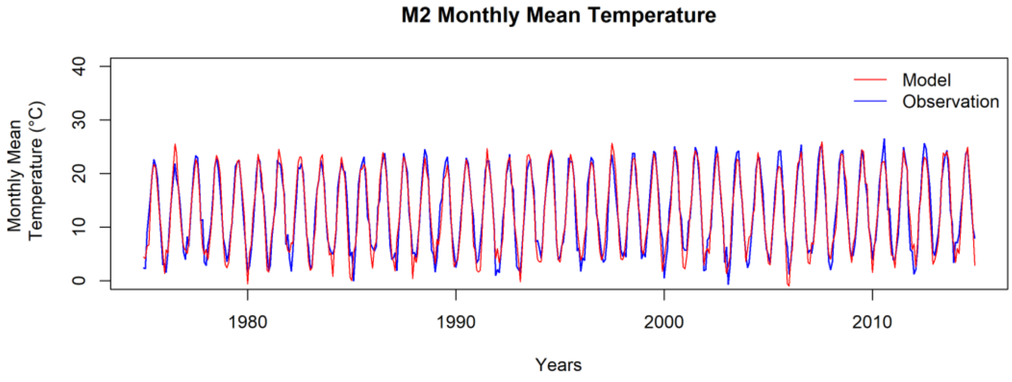

M5 Monthly Mean Temperature
Model
Observation
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years

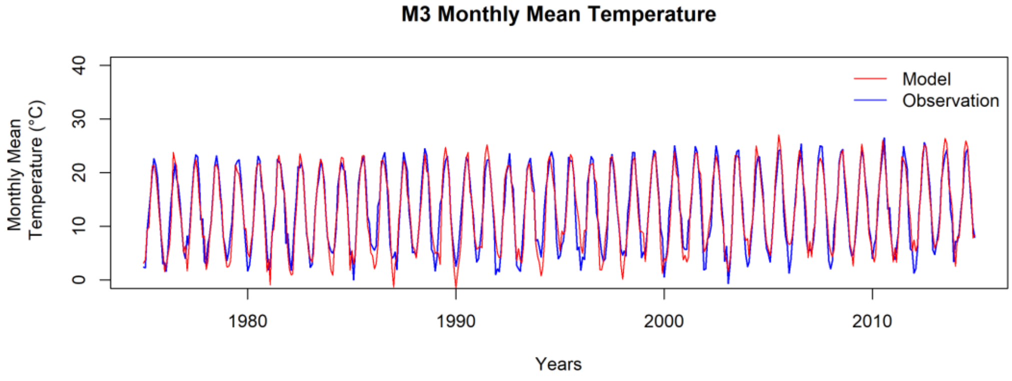

M7 Monthly Mean Temperature
Model
Observation
Ensemble Member
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years

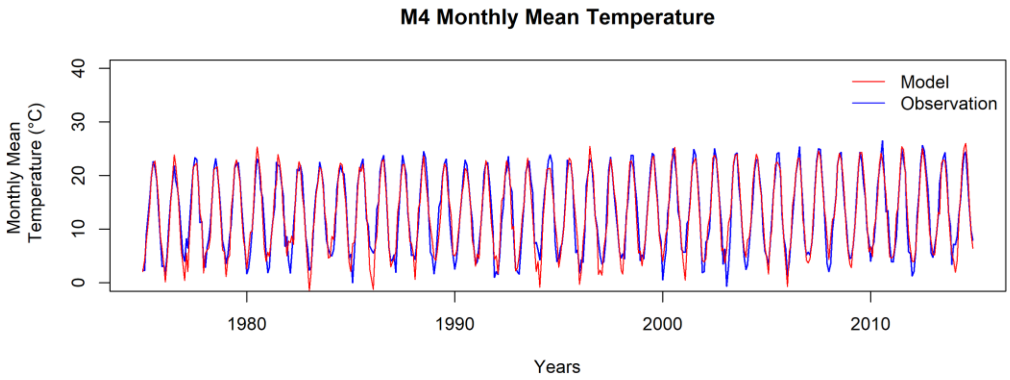

M9 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

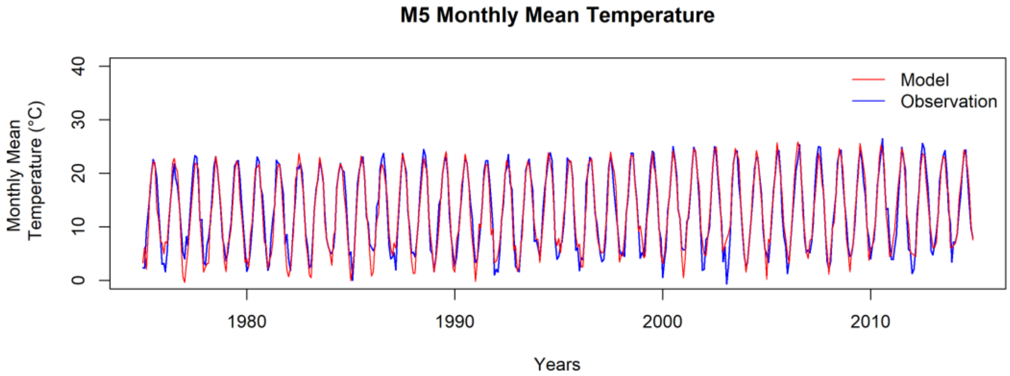
<u>G18 Subbasin Monthly Mean Temperature</u>

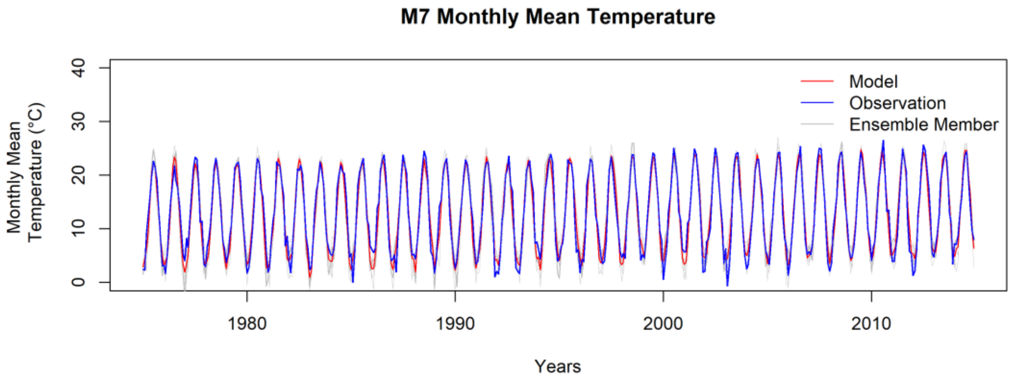


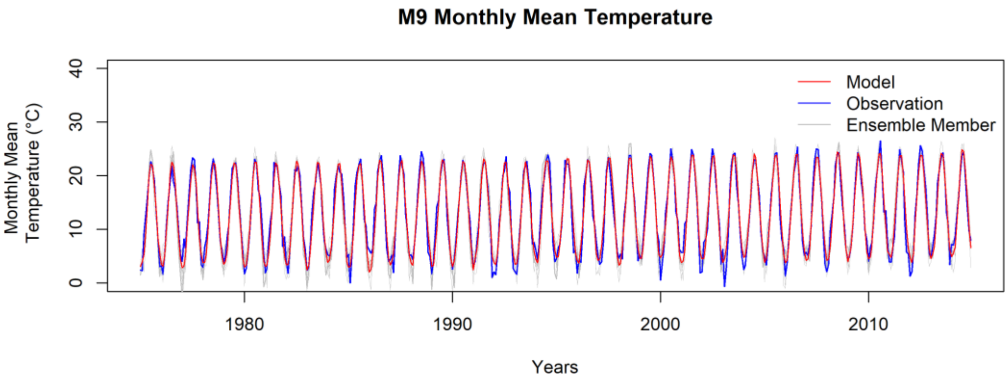




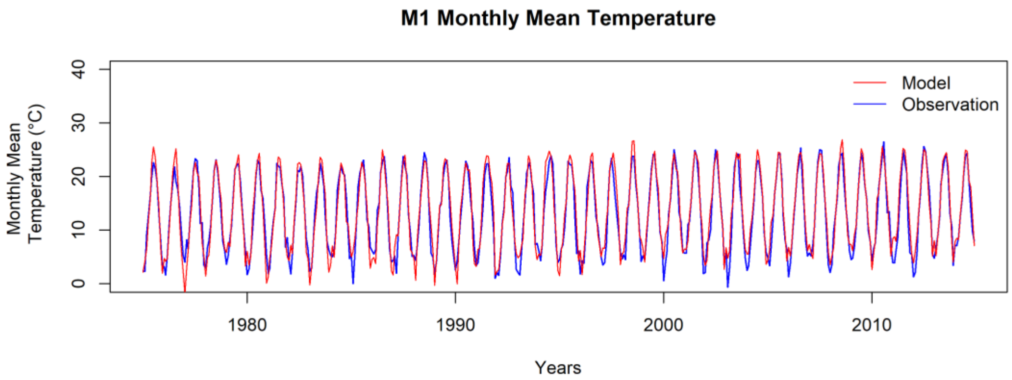

M4 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation

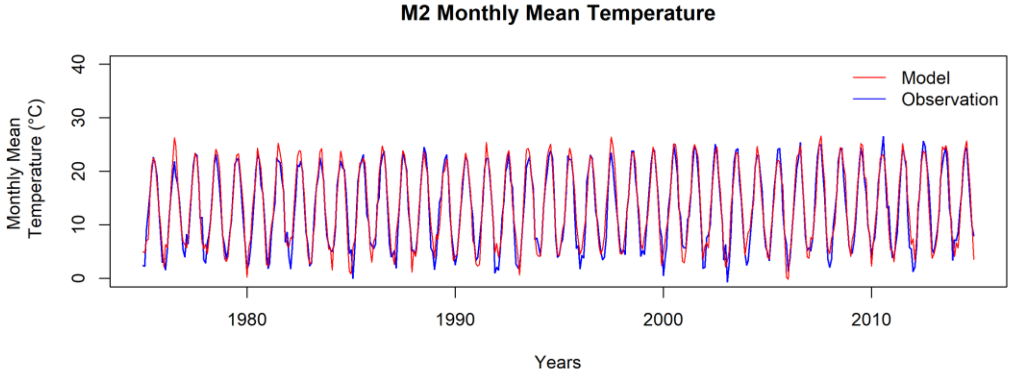

M5 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation

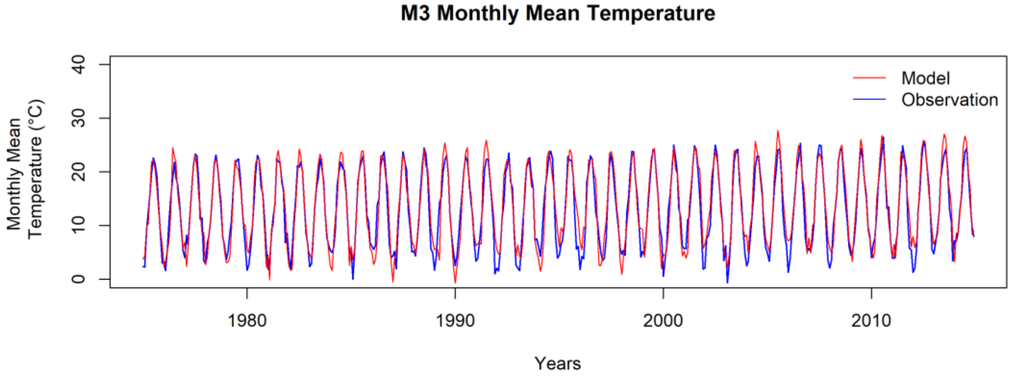

M7 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

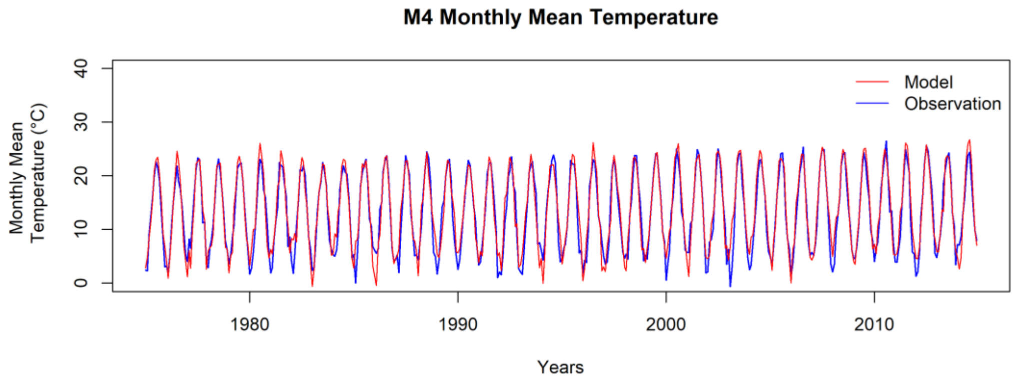

M9 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

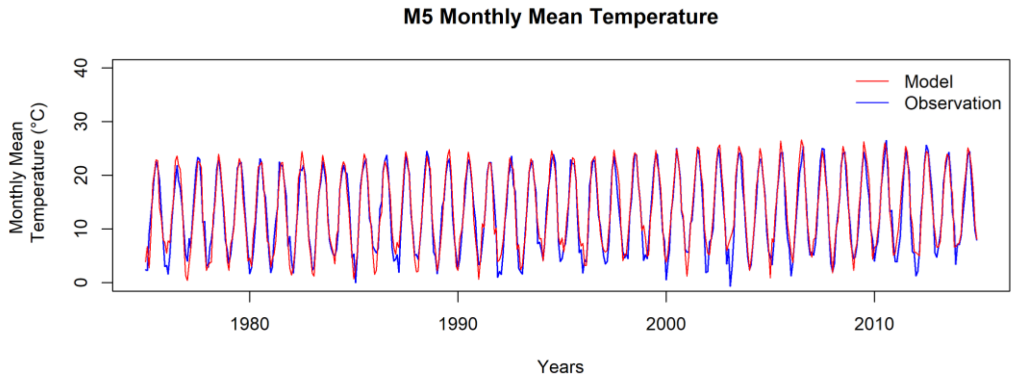
N14 Subbasin Monthly Mean Temperature

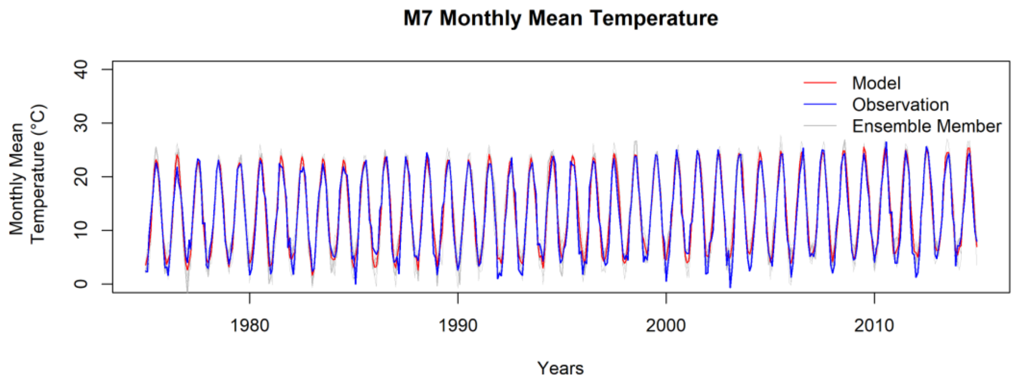


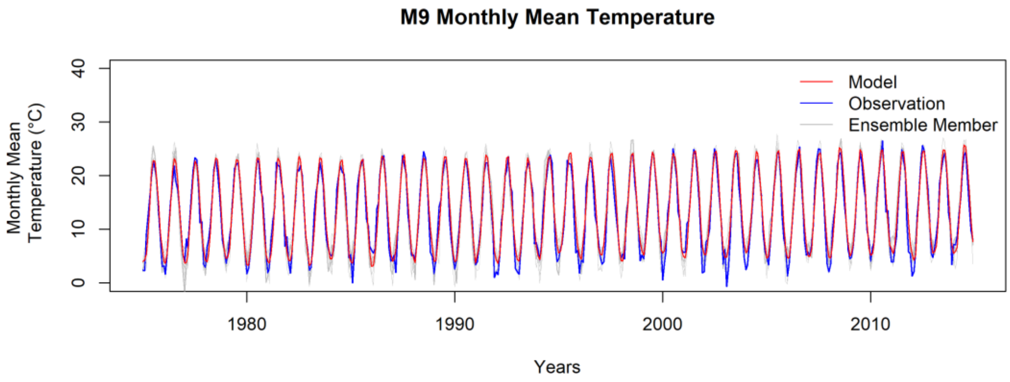




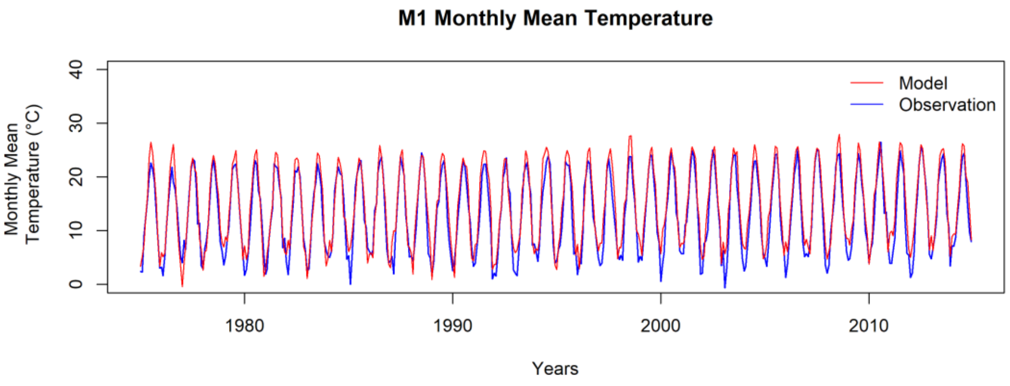

M4 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation

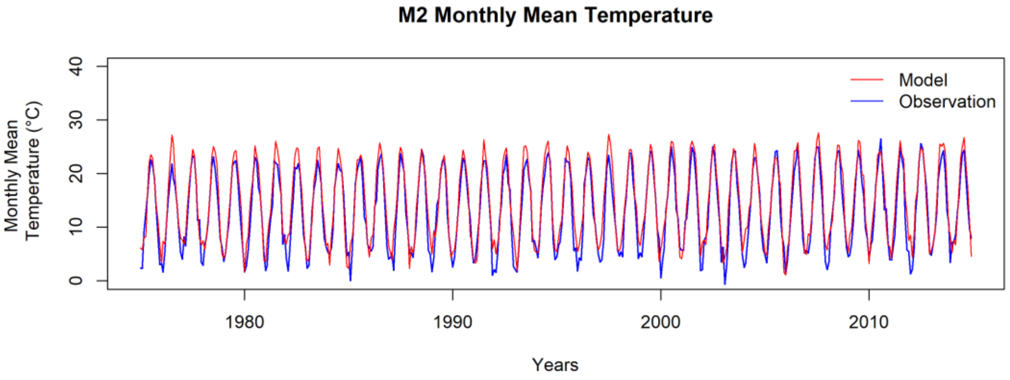

M5 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation

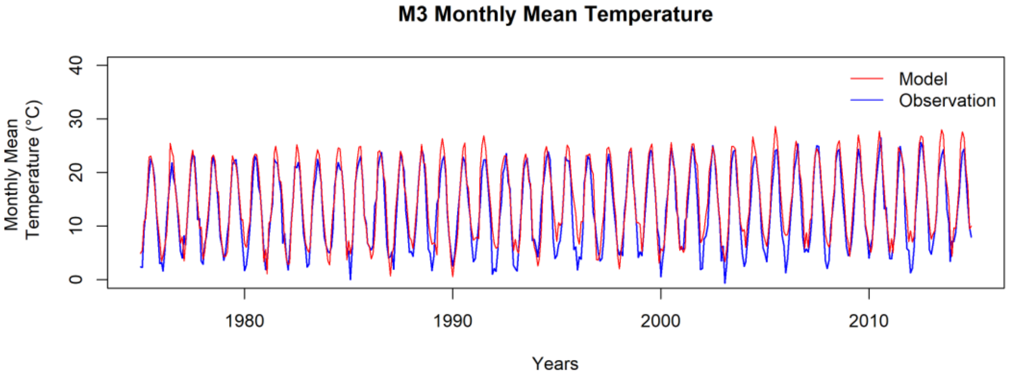

M7 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

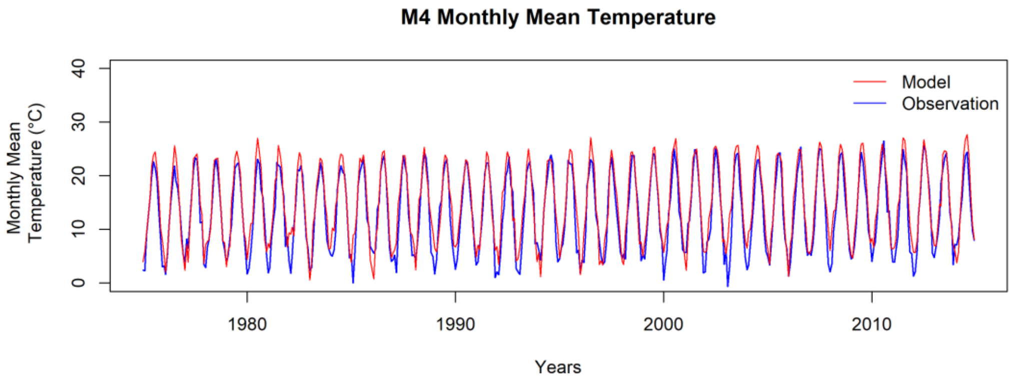

M9 Monthly Mean Temperature
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

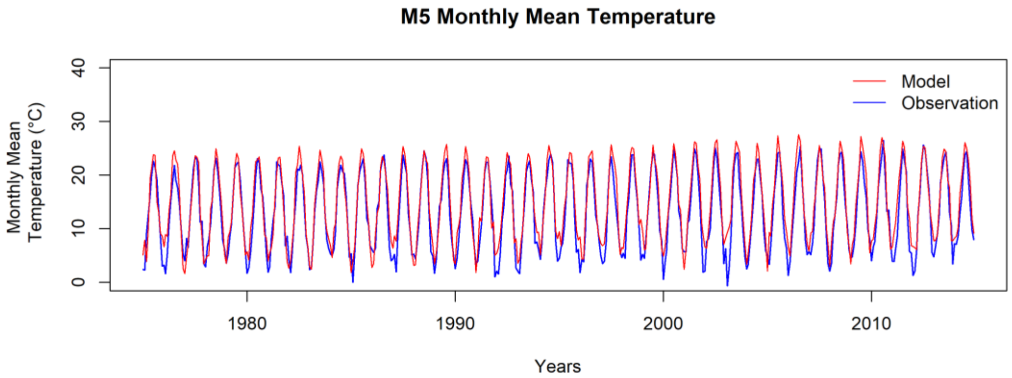
N15 Subbasin Monthly Mean Temperature

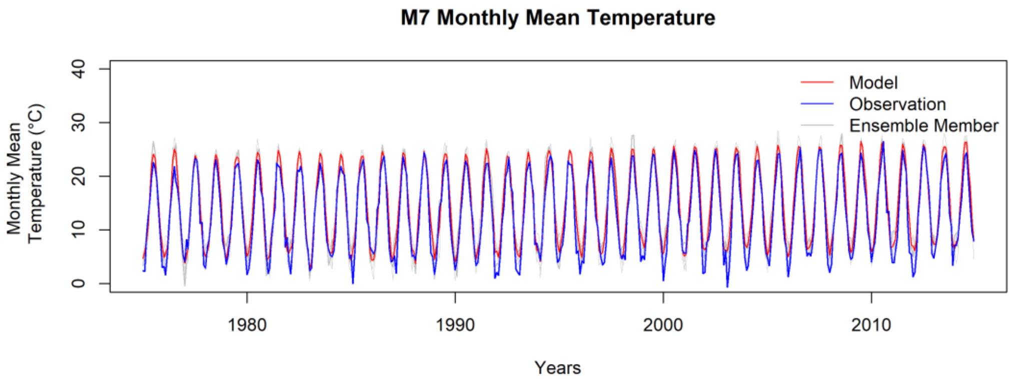


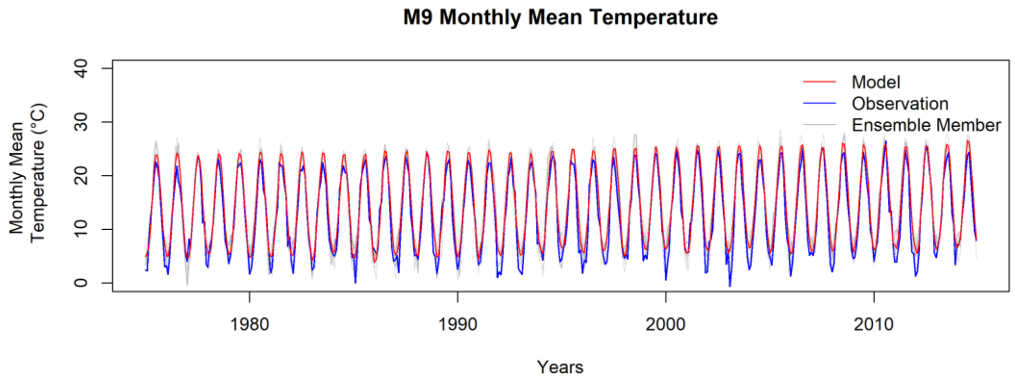




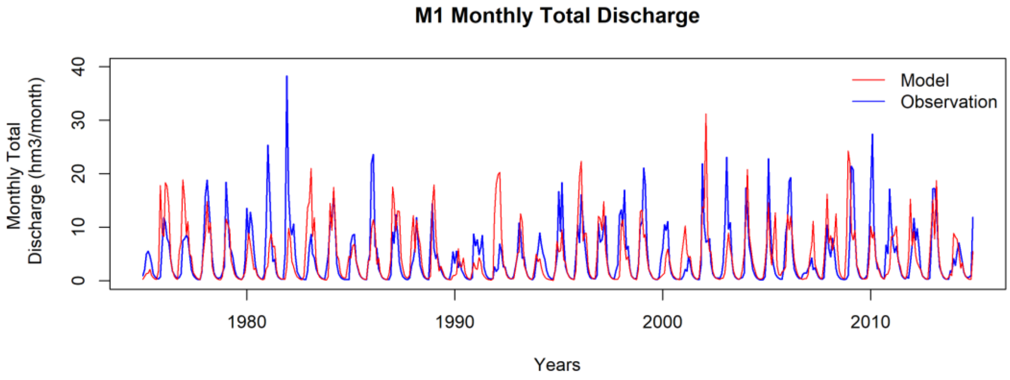

M4 Monthly Mean Temperature
Model
Observation
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years

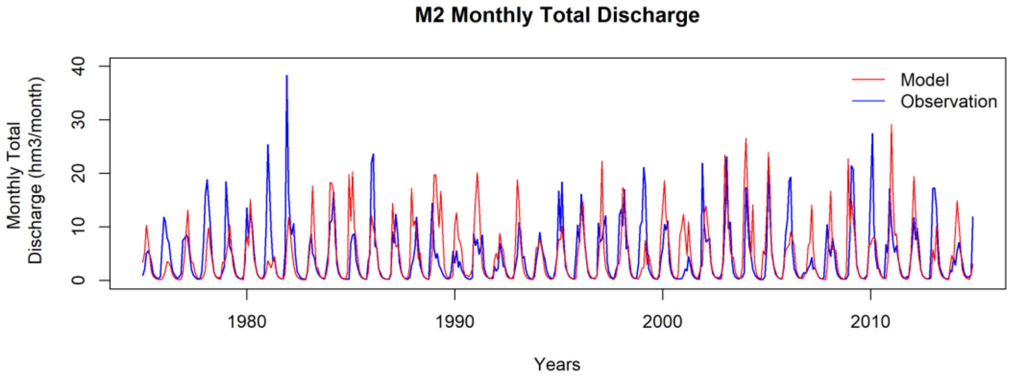

M5 Monthly Mean Temperature
Model
Observation
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years

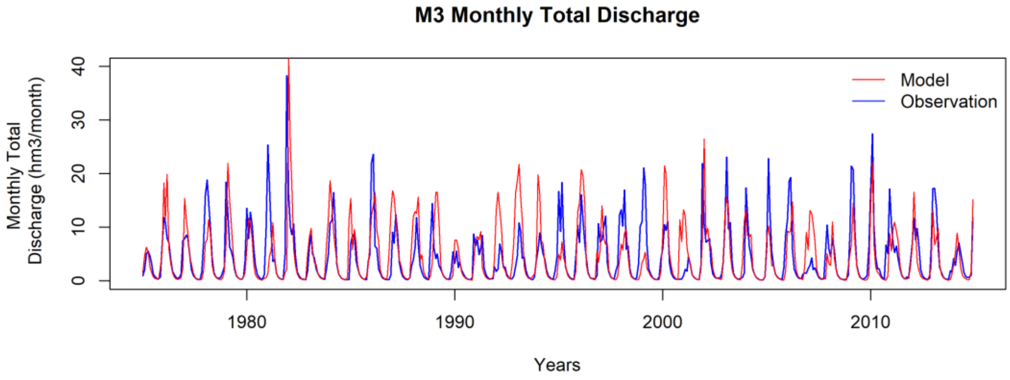

M7 Monthly Mean Temperature
Model
Observation
Ensemble Member
Monthly Mean Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years


M9 Monthly Mean Temperature
Monthly Mean
Temperature (°C)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

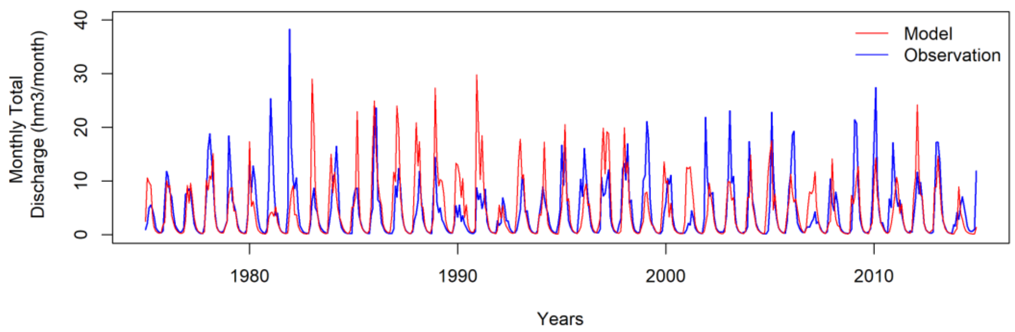
G03 Subbasin Monthly Total Discharge



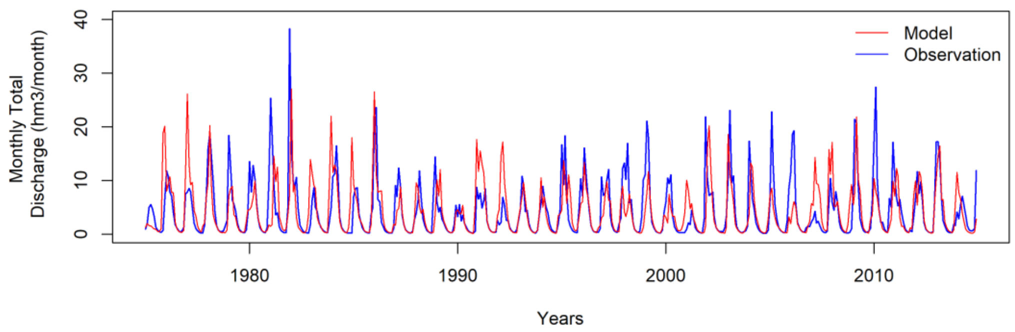




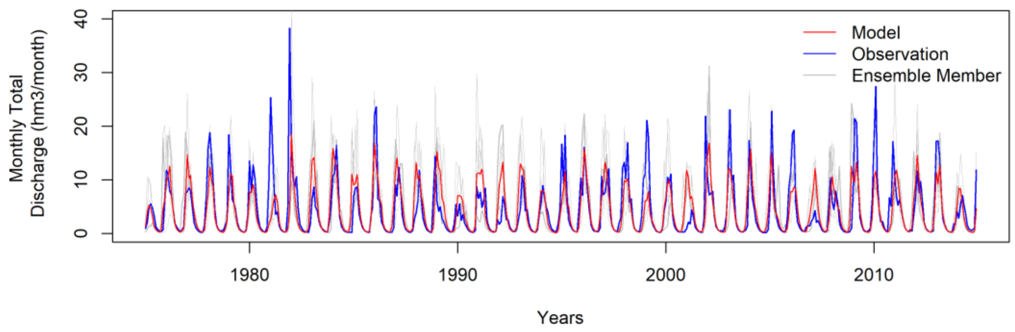
M4 Monthly Total Discharge

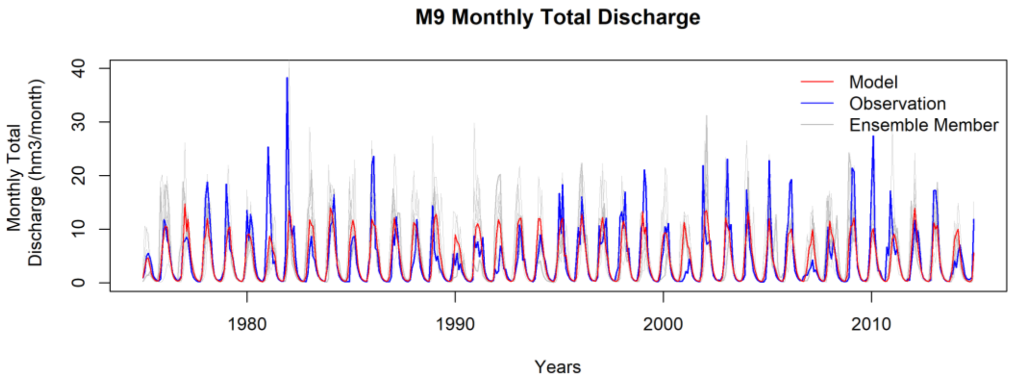


M5 Monthly Total Discharge

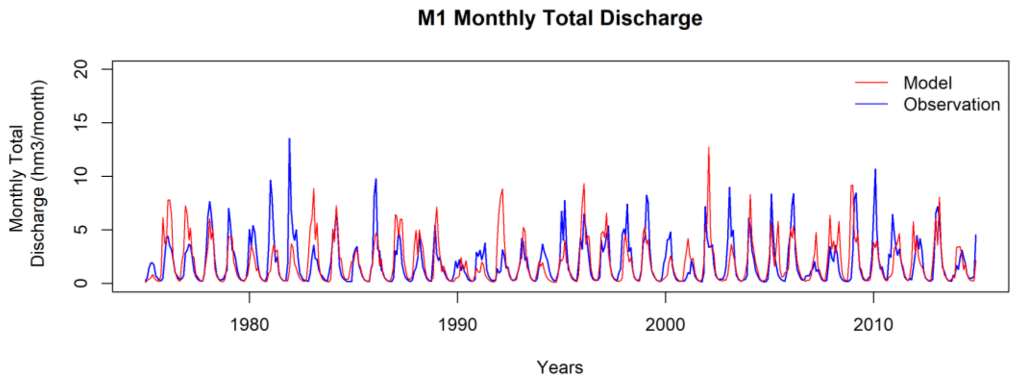


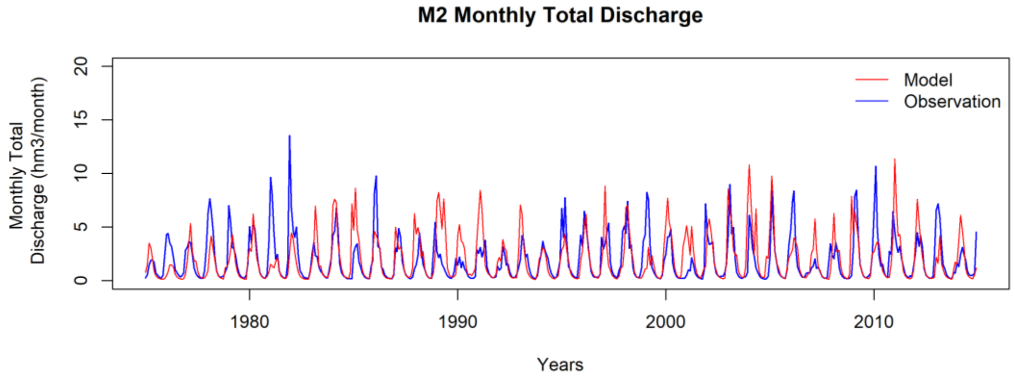
M7 Monthly Total Discharge

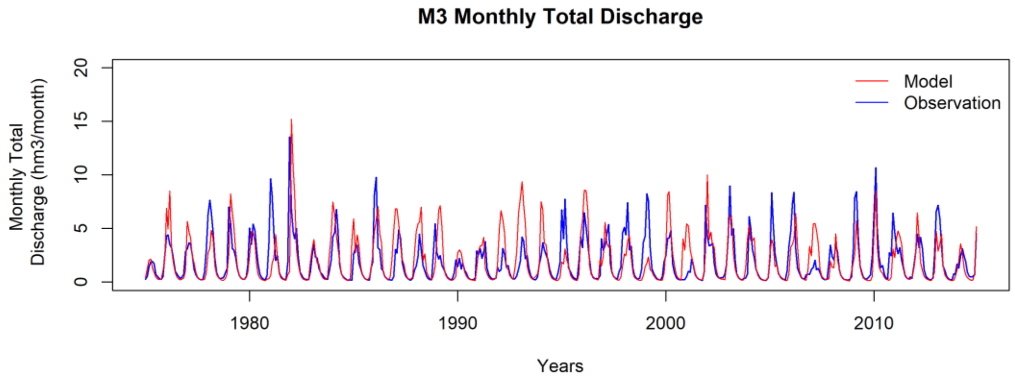



M9 Monthly Total Discharge
Model
Observation
Ensemble Member
Monthly Total
Discharge (hm3/month)
0
10
20
30
40
1980
1990
2000
2010
Years

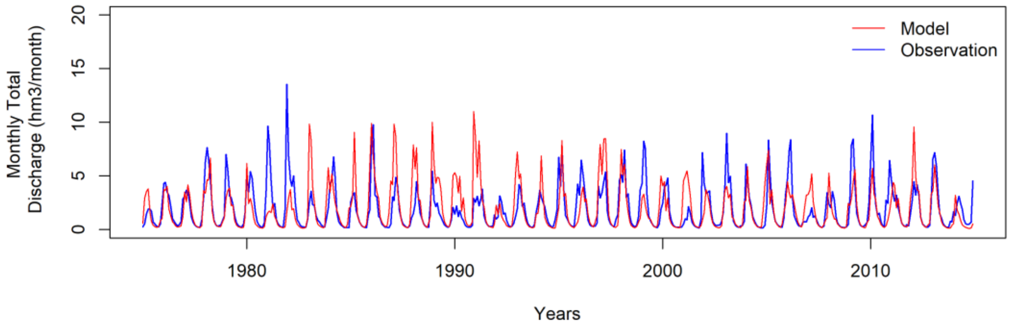
G12 Subbasin Monthly Total Discharge



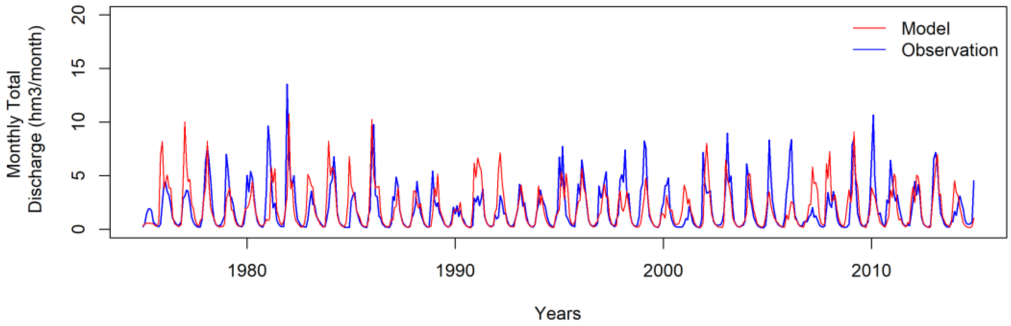




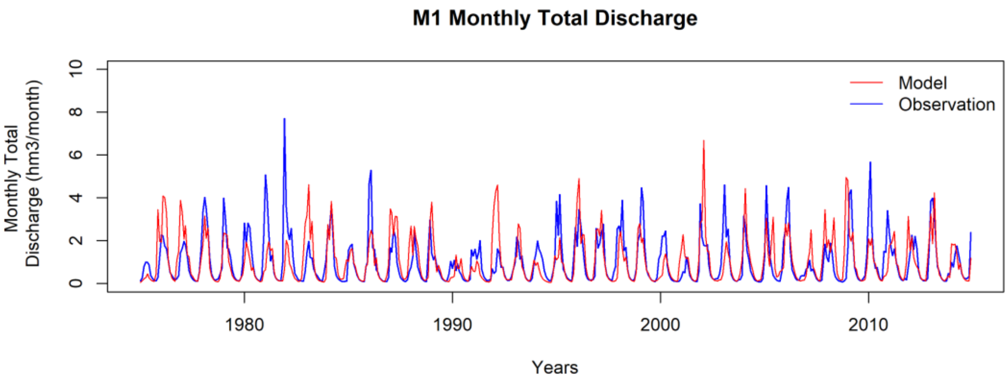
M4 Monthly Total Discharge

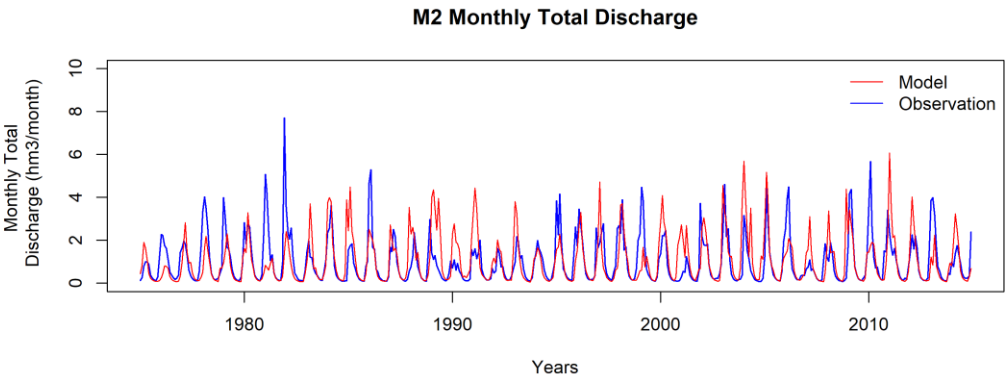


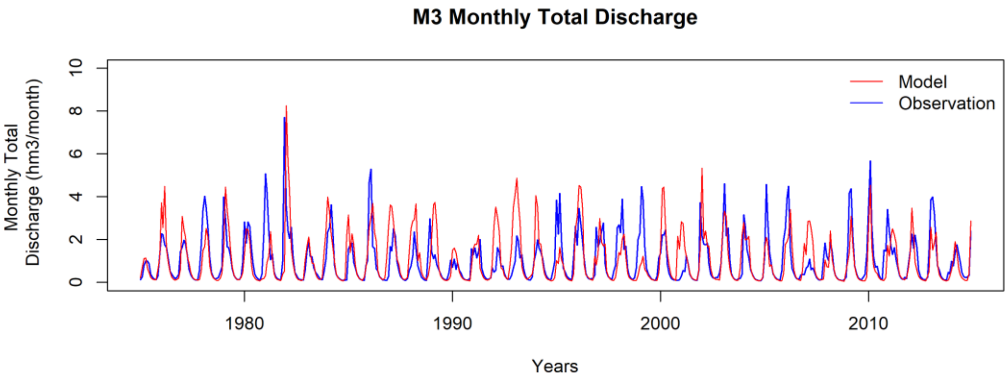
M5 Monthly Total Discharge

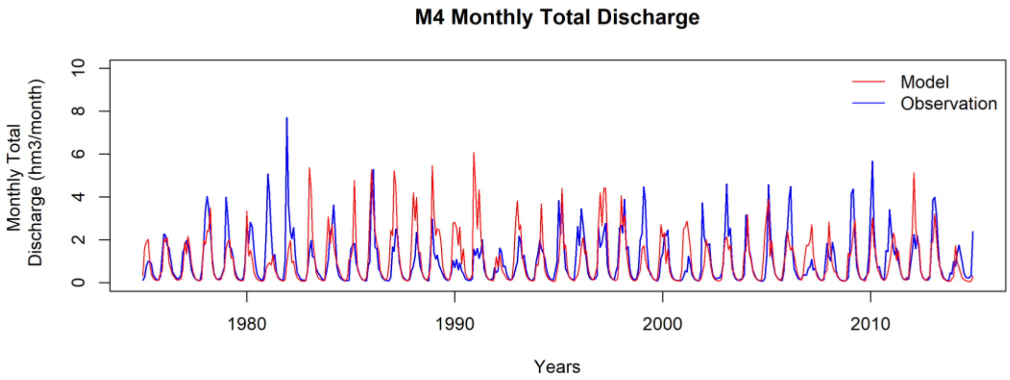


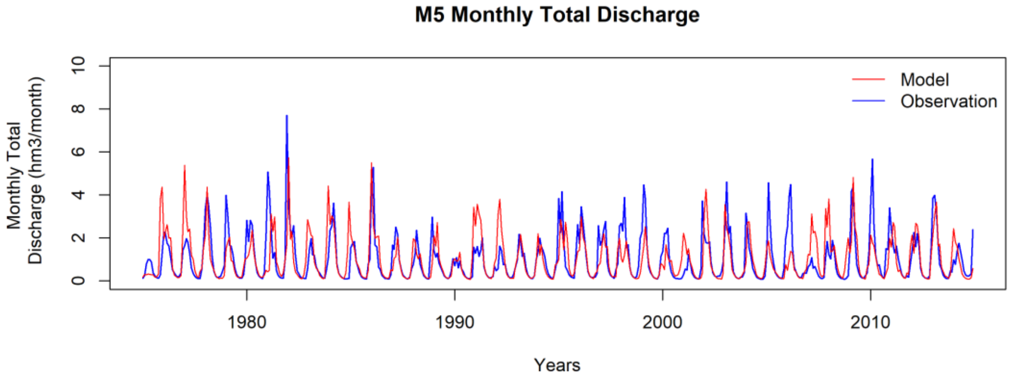
G18 Subbasin Monthly Total Discharge

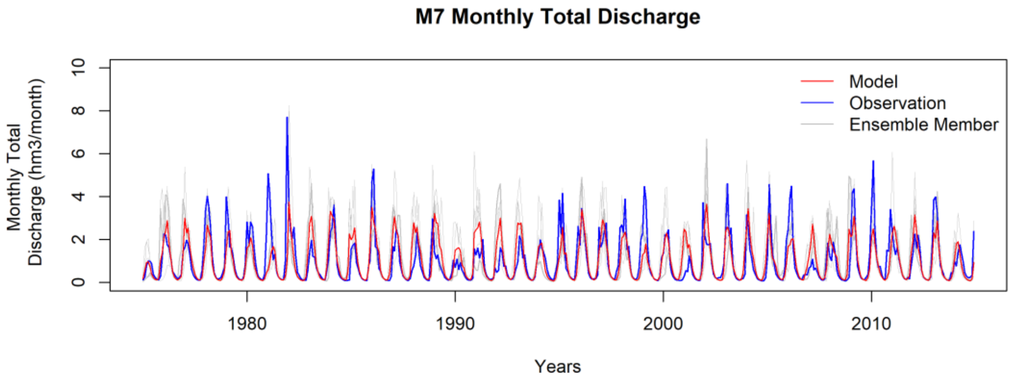


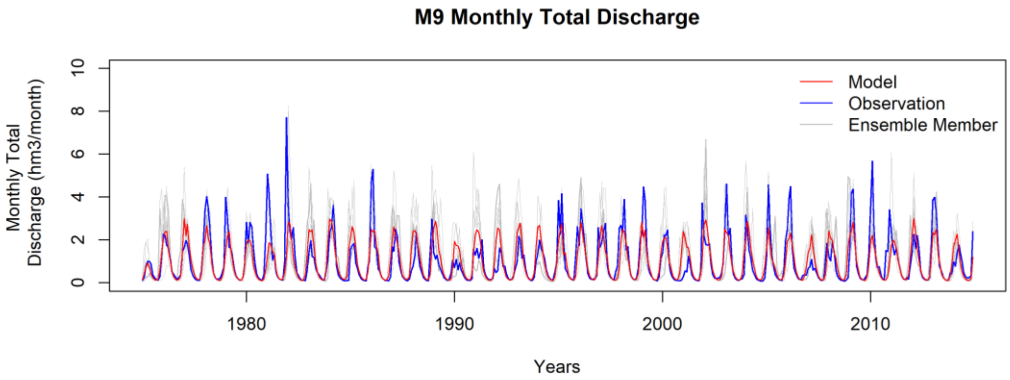




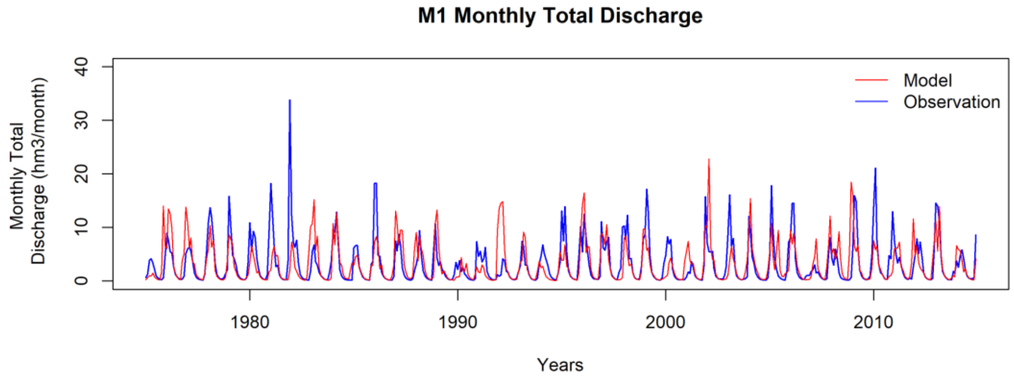

M4 Monthly Total Discharge
Monthly Total Discharge (hm3/month)
0
2
4
6
8
10
1980
1990
2000
2010
Years
Model
Observation

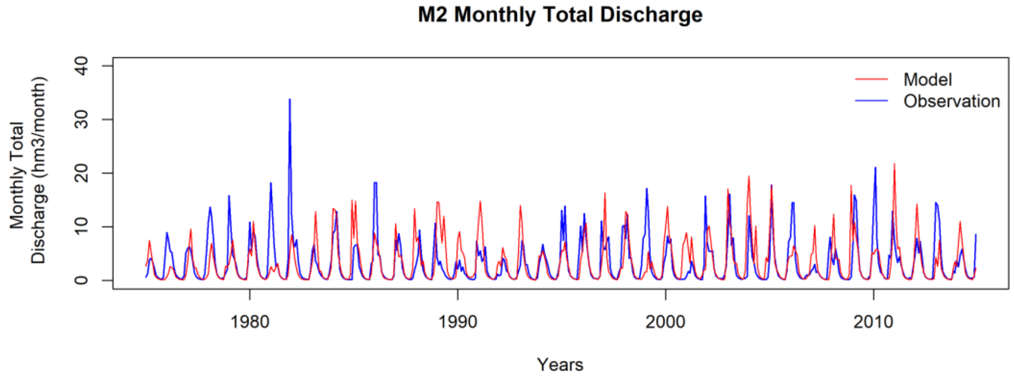

M5 Monthly Total Discharge
Monthly Total Discharge (hm3/month)
0
2
4
6
8
10
1980
1990
2000
2010
Years
Model
Observation

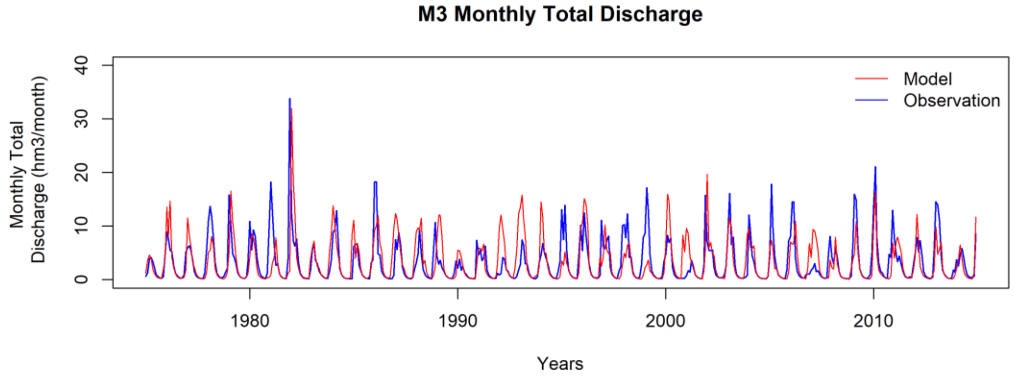

M7 Monthly Total Discharge
Monthly Total Discharge (hm3/month)
0
2
4
6
8
10
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member


M9 Monthly Total Discharge
Monthly Total
Discharge (hm3/month)
0
2
4
6
8
10
Model
Observation
Ensemble Member
1980
1990
2000
2010
Years

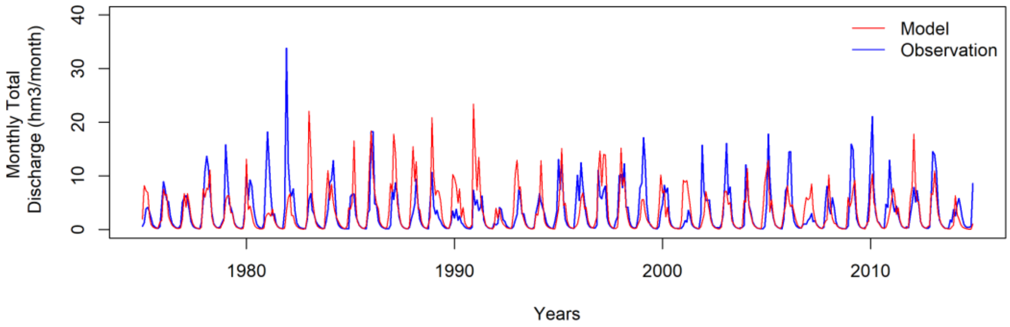
N14 Subbasin Monthly Total Discharge



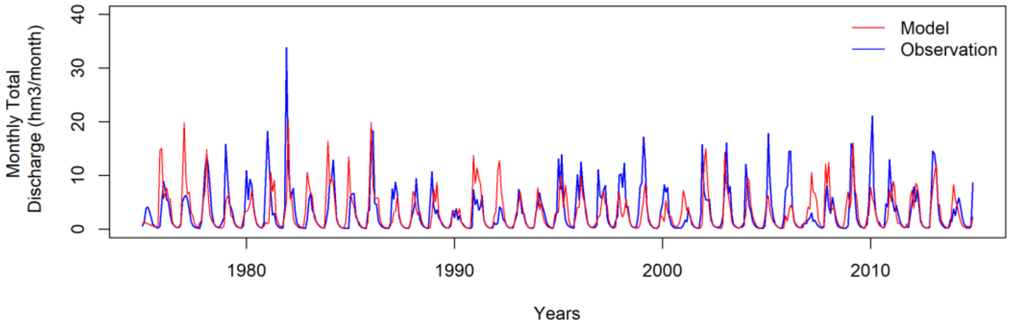




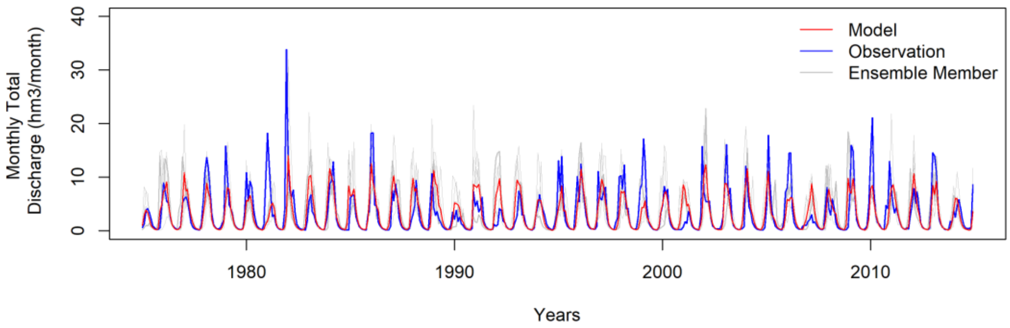
M4 Monthly Total Discharge

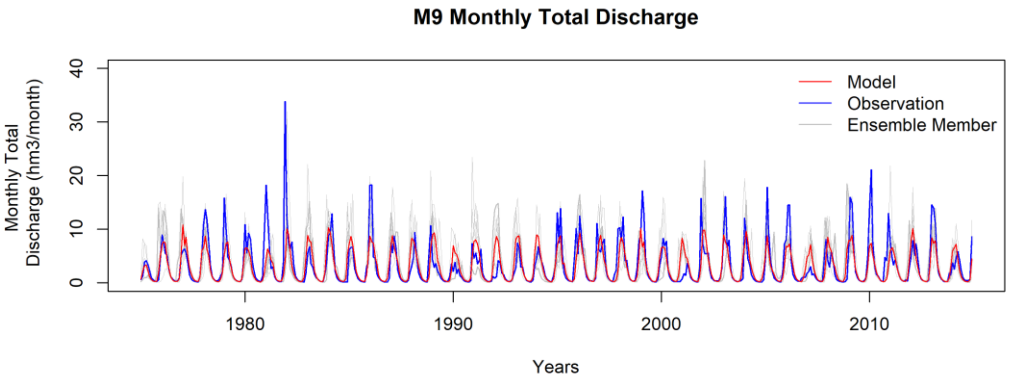


M5 Monthly Total Discharge



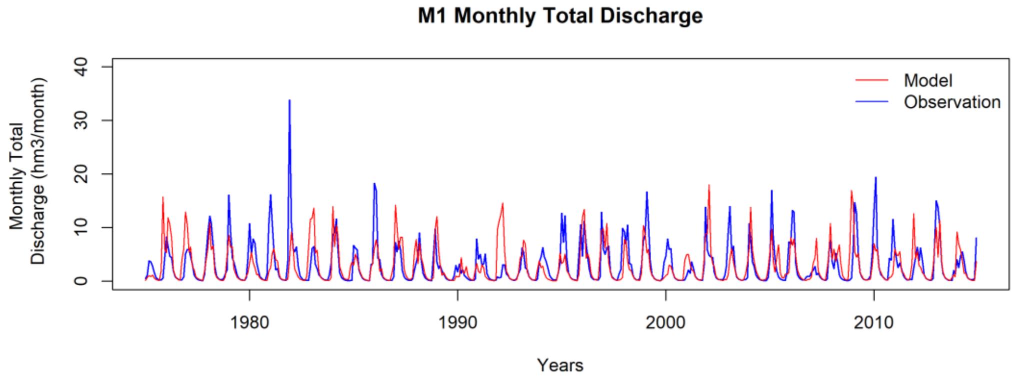
M7 Monthly Total Discharge

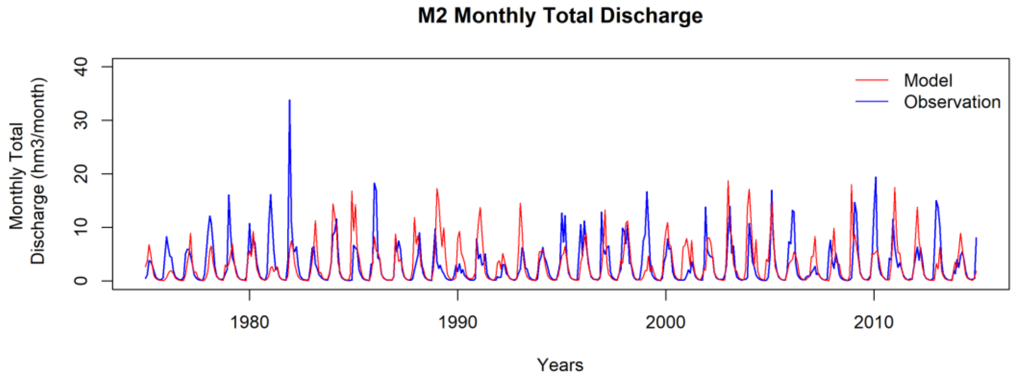


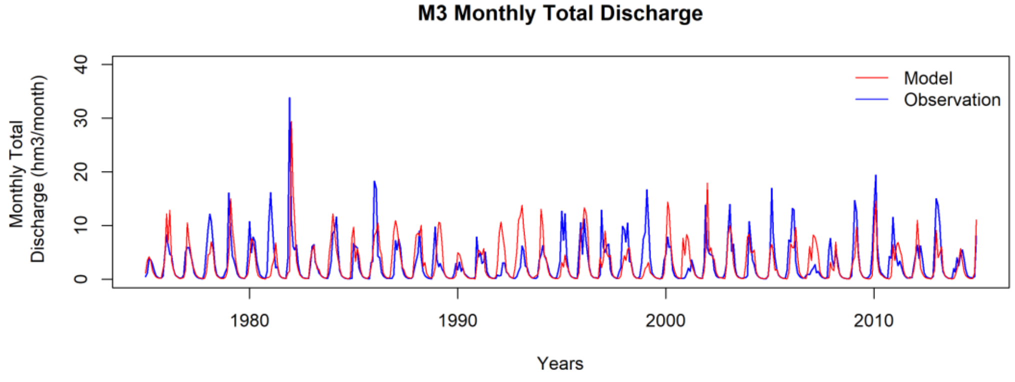


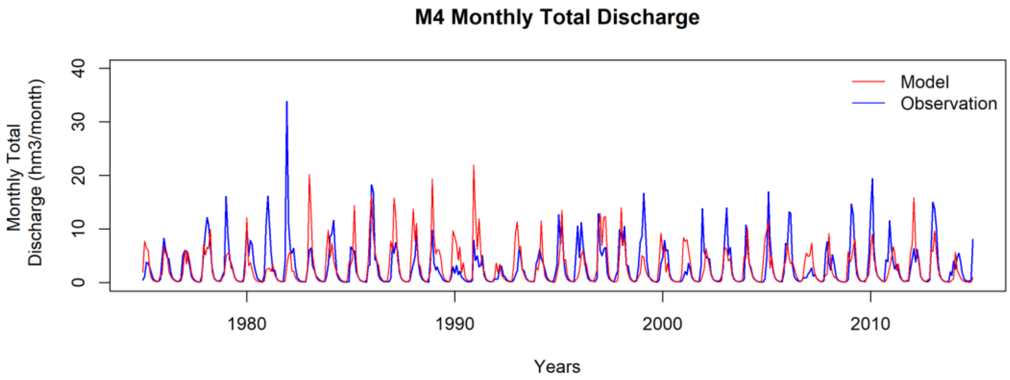
M9 Monthly Total Discharge
Monthly Total Discharge (hm3/month)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

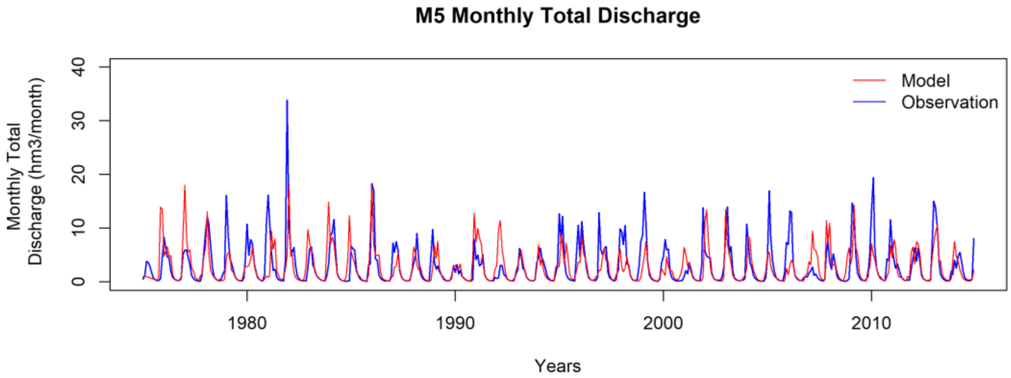
N15 Subbasin Monthly Total Discharge

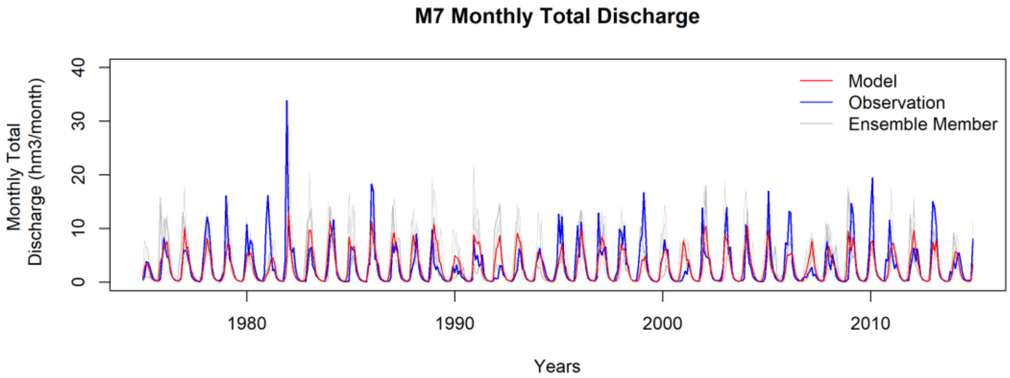


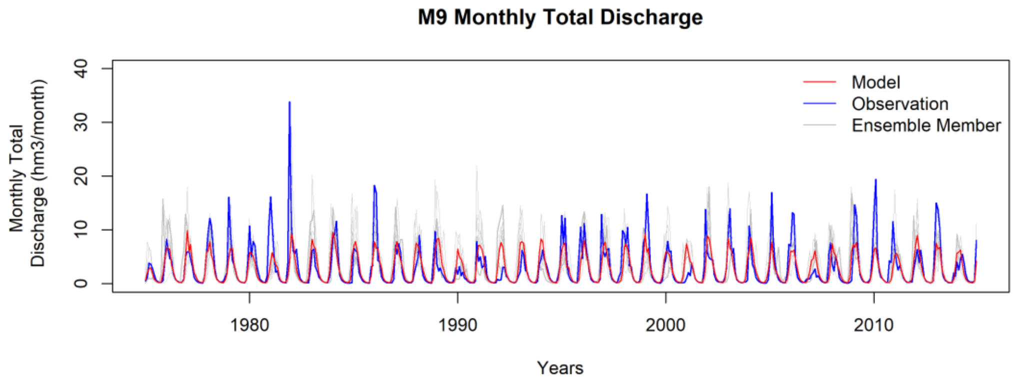





M4 Monthly Total Discharge
Monthly Total Discharge (hm3/month)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation


M5 Monthly Total Discharge
Monthly Total Discharge (hm3/month)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation


M7 Monthly Total Discharge
Monthly Total Discharge (hm3/month)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member


M9 Monthly Total Discharge
Monthly Total
Discharge (hm3/month)
0
10
20
30
40
1980
1990
2000
2010
Years
Model
Observation
Ensemble Member

C. Trend Analysis

Precipitation

Monthly, seasonal and annual precipitation trends for G03 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.34	-0.12	-0.93	-0.60	-0.39	-0.11	-0.22	-0.19	0.75	0.72	-0.61	-0.37	-0.26	-0.15
February	0.29	0.09	0.18	0.10	0.21	0.12	0.79	0.53	1.36	0.48	-0.93	-0.45	0.93	0.80
March	0.31	0.10	-0.32	-0.13	0.36	0.15	0.40	0.23	0.25	0.09	1.43	0.51	-0.57	-0.31
April	0.34	0.11	0.14	0.04	0.64	0.50	-2.69	-1.32	-0.82	-0.53	-0.82	-0.36	-0.04	-0.09
May	0.52	0.18	-0.14	-0.04	-1.36	-0.71	-1.41	-0.67	-0.18	-0.10	-1.39	-0.41	-1.68	-0.79
June	1.25	0.30	-0.32	-0.09	-1.50	-0.51	0.93	0.31	0.43	0.12	1.03	0.25	-1.50	-0.49
July	0.41	0.04	-1.39	-0.20	-0.25	-0.01	0.26	0.04	0.32	0.03	-0.25	-0.02	-0.13	-0.01
August	0.20	0.01	1.25	0.05	-0.71	-0.01	1.10	0.05	-0.86	-0.03	-2.28	-0.07	-0.31	-0.01
September	-0.55	-0.08	0.11	0.04	-1.43	-0.24	0.40	0.10	1.03	0.16	-1.07	-0.17	0.88	0.16
October	-0.62	-0.28	-0.36	-0.16	-0.18	-0.19	-2.07	-1.87	-1.50	-0.62	-1.43	-0.80	0.97	0.58
November	0.36	0.18	-0.64	-0.49	1.93	1.52	0.88	0.76	-0.93	-0.45	-2.11	-1.37	-0.57	-0.40
December	0.36	0.14	0.64	0.39	0.07	0.04	1.28	1.27	-0.68	-0.39	1.07	0.81	-0.09	-0.05
Spring	0.90	0.14	-0.04	-0.01	-0.57	-0.12	-1.94	-0.61	-0.71	-0.18	0.39	0.11	-0.04	-0.02
Summer	1.06	0.09	-0.86	-0.06	-1.18	-0.17	0.75	0.10	0.29	0.03	0.07	0.00	-1.72	-0.13
Fall	-0.01	0.00	-0.93	-0.22	0.61	0.21	-0.53	-0.26	-1.28	-0.35	-3.71	-0.69	0.48	0.15
Winter	0.17	0.06	-0.32	-0.08	0.25	0.13	1.19	0.69	0.46	0.19	0.32	0.14	-0.04	-0.01
Annual	0.59	0.04	-0.46	-0.07	0.43	0.05	-0.35	-0.10	-0.68	-0.06	-1.28	-0.18	-0.40	-0.07

Monthly, seasonal and annual precipitation trends for G03 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	1.18	0.32	-0.64	-0.26	0.00	0.00	0.62	0.20	0.93	0.41	-0.57	-0.30	-0.84	-0.52
February	-0.17	-0.05	0.71	0.27	1.14	0.54	0.13	0.12	-1.21	-0.30	-0.54	-0.12	0.53	0.24
March	0.76	0.14	-0.14	-0.09	-0.36	-0.09	0.35	0.14	0.29	0.07	0.61	0.23	-0.48	-0.30
April	-0.55	-0.07	0.68	0.14	-1.96	-0.46	-1.63	-0.43	-0.96	-0.27	-0.07	-0.07	-0.22	-0.10
May	0.57	0.11	-0.32	-0.14	-1.11	-0.34	-2.34	-1.01	-1.43	-0.46	-1.75	-0.43	0.00	0.03
June	2.18	0.32	-1.36	-0.24	-1.53	-0.34	0.35	0.07	1.61	0.35	0.93	0.21	0.31	0.08
July	0.43	0.03	-0.96	-0.13	-0.18	-0.02	0.09	0.02	1.28	0.12	-0.61	-0.03	0.40	0.03
August	0.52	0.04	1.75	0.12	-1.00	-0.05	1.01	0.09	-0.18	-0.01	-1.89	-0.09	0.22	0.00
September	-0.97	-0.11	0.32	0.05	0.32	0.06	0.57	0.08	0.07	0.00	-0.36	-0.07	0.62	0.11
October	-0.62	-0.12	-0.29	-0.07	0.14	0.08	-0.35	-0.24	-1.32	-0.46	-1.07	-0.31	1.28	0.66
November	-0.01	0.00	-0.64	-0.20	0.93	0.53	0.31	0.17	-1.11	-0.53	-1.93	-0.85	-0.66	-0.23
December	-0.69	-0.17	1.18	0.62	-0.11	-0.03	0.71	0.26	-0.86	-0.50	1.00	0.42	-1.41	-0.52
Spring	0.10	0.03	-0.50	-0.09	-2.11	-0.29	-1.41	-0.46	-1.43	-0.28	-0.61	-0.11	-0.22	-0.04
Summer	2.02	0.12	-0.75	-0.07	-1.11	-0.09	0.09	0.03	1.11	0.10	-0.18	-0.01	0.44	0.08
Fall	-0.80	-0.09	-0.32	-0.08	0.39	0.11	0.35	0.09	-0.93	-0.18	-2.39	-0.34	1.23	0.20
Winter	-0.01	-0.01	0.54	0.13	0.29	0.09	0.22	0.13	-0.57	-0.16	0.39	0.09	-0.48	-0.18
Annual	-0.08	0.00	0.07	0.02	-0.04	0.00	-0.62	-0.08	-1.50	-0.13	-1.46	-0.09	0.04	0.02

Monthly, seasonal and annual precipitation trends for G12 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.34	-0.13	-0.89	-0.62	-0.39	-0.13	-0.26	-0.20	0.75	0.74	-0.68	-0.41	-0.35	-0.18
February	0.34	0.08	0.14	0.10	0.14	0.13	0.84	0.54	1.36	0.48	-0.89	-0.46	0.93	0.86
March	0.34	0.11	-0.39	-0.15	0.36	0.16	0.40	0.30	0.25	0.09	1.46	0.52	-0.48	-0.31
April	0.38	0.09	0.07	0.04	0.71	0.51	-2.69	-1.40	-0.82	-0.57	-0.86	-0.37	-0.04	-0.07
May	0.50	0.18	-0.11	-0.03	-1.32	-0.73	-1.37	-0.70	-0.18	-0.12	-1.39	-0.43	-1.72	-0.83
June	1.22	0.32	-0.32	-0.11	-1.43	-0.53	0.88	0.31	0.43	0.12	1.03	0.25	-1.50	-0.52
July	0.34	0.03	-1.36	-0.22	-0.21	-0.02	0.31	0.05	0.32	0.03	-0.29	-0.01	-0.13	-0.01
August	0.20	0.01	1.11	0.05	-0.68	-0.01	0.97	0.05	-1.03	-0.03	-2.25	-0.08	-0.35	-0.01
September	-0.52	-0.08	0.14	0.04	-1.43	-0.25	0.40	0.10	1.00	0.17	-1.07	-0.17	0.84	0.14
October	-0.69	-0.29	-0.43	-0.18	-0.25	-0.21	-2.03	-2.01	-1.43	-0.69	-1.43	-0.84	0.88	0.64
November	0.38	0.19	-0.68	-0.50	1.93	1.61	0.93	0.82	-0.86	-0.47	-2.14	-1.39	-0.53	-0.40
December	0.31	0.15	0.64	0.38	0.07	0.08	1.32	1.31	-0.64	-0.42	1.03	0.83	-0.09	-0.06
Spring	0.85	0.15	0.00	0.00	-0.50	-0.09	-1.94	-0.64	-0.68	-0.19	0.36	0.11	-0.04	-0.03
Summer	1.01	0.10	-0.79	-0.08	-1.11	-0.19	0.71	0.11	0.29	0.03	0.00	0.00	-1.76	-0.14
Fall	0.00	0.00	-1.00	-0.23	0.54	0.21	-0.53	-0.30	-1.28	-0.36	-3.68	-0.71	0.44	0.14
Winter	0.17	0.07	-0.32	-0.09	0.25	0.11	1.23	0.75	0.43	0.18	0.36	0.13	-0.09	-0.02
Annual	0.48	0.04	-0.50	-0.07	0.43	0.05	-0.35	-0.11	-0.68	-0.07	-1.28	-0.20	-0.44	-0.07

Monthly, seasonal and annual precipitation trends for G12 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	1.18	0.32	-0.64	-0.26	0.00	0.00	0.62	0.20	0.93	0.41	-0.57	-0.30	-0.84	-0.52
February	-0.17	-0.05	0.71	0.27	1.14	0.54	0.13	0.12	-1.21	-0.30	-0.54	-0.12	0.53	0.24
March	0.76	0.14	-0.14	-0.09	-0.36	-0.09	0.35	0.14	0.29	0.07	0.61	0.23	-0.48	-0.30
April	-0.55	-0.07	0.68	0.14	-1.96	-0.46	-1.63	-0.43	-0.96	-0.27	-0.07	-0.07	-0.22	-0.10
May	0.57	0.11	-0.32	-0.14	-1.11	-0.34	-2.34	-1.01	-1.43	-0.46	-1.75	-0.43	0.00	0.03
June	2.18	0.32	-1.36	-0.24	-1.53	-0.34	0.35	0.07	1.61	0.35	0.93	0.21	0.31	0.08
July	0.43	0.03	-0.96	-0.13	-0.18	-0.02	0.09	0.02	1.28	0.12	-0.61	-0.03	0.40	0.03
August	0.52	0.04	1.75	0.12	-1.00	-0.05	1.01	0.09	-0.18	-0.01	-1.89	-0.09	0.22	0.00
September	-0.97	-0.11	0.32	0.05	0.32	0.06	0.57	0.08	0.07	0.00	-0.36	-0.07	0.62	0.11
October	-0.62	-0.12	-0.29	-0.07	0.14	0.08	-0.35	-0.24	-1.32	-0.46	-1.07	-0.31	1.28	0.66
November	-0.01	0.00	-0.64	-0.20	0.93	0.53	0.31	0.17	-1.11	-0.53	-1.93	-0.85	-0.66	-0.23
December	-0.69	-0.17	1.18	0.62	-0.11	-0.03	0.71	0.26	-0.86	-0.50	1.00	0.42	-1.41	-0.52
Spring	0.10	0.03	-0.50	-0.09	-2.11	-0.29	-1.41	-0.46	-1.43	-0.28	-0.61	-0.11	-0.22	-0.04
Summer	2.02	0.12	-0.75	-0.07	-1.11	-0.09	0.09	0.03	1.11	0.10	-0.18	-0.01	0.44	0.08
Fall	-0.80	-0.09	-0.32	-0.08	0.39	0.11	0.35	0.09	-0.93	-0.18	-2.39	-0.34	1.23	0.20
Winter	-0.01	-0.01	0.54	0.13	0.29	0.09	0.22	0.13	-0.57	-0.16	0.39	0.09	-0.48	-0.18
Annual	-0.08	0.00	0.07	0.02	-0.04	0.00	-0.62	-0.08	-1.50	-0.13	-1.46	-0.09	0.04	0.02

Monthly, seasonal and annual precipitation trends for G18 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.38	-0.13	-0.89	-0.69	-0.29	-0.14	-0.26	-0.25	0.75	0.79	-0.68	-0.44	-0.31	-0.17
February	0.27	0.09	0.11	0.13	0.21	0.21	0.79	0.59	1.36	0.51	-0.86	-0.47	0.93	0.88
March	0.31	0.10	-0.36	-0.15	0.36	0.18	0.40	0.31	0.25	0.08	1.39	0.57	-0.44	-0.34
April	0.34	0.11	0.11	0.04	0.64	0.57	-2.69	-1.46	-0.86	-0.58	-0.79	-0.39	-0.04	-0.12
May	0.52	0.19	-0.11	-0.04	-1.36	-0.76	-1.41	-0.74	-0.18	-0.13	-1.39	-0.45	-1.68	-0.87
June	1.22	0.32	-0.29	-0.11	-1.50	-0.55	0.88	0.35	0.50	0.13	1.03	0.27	-1.50	-0.54
July	0.41	0.04	-1.39	-0.23	-0.25	-0.01	0.26	0.04	0.32	0.03	-0.21	-0.02	-0.04	-0.02
August	0.15	0.01	1.07	0.05	-0.54	-0.01	0.97	0.05	-1.11	-0.04	-2.28	-0.08	-0.26	-0.01
September	-0.52	-0.09	0.07	0.05	-1.32	-0.23	0.44	0.09	1.00	0.19	-1.03	-0.18	0.88	0.15
October	-0.64	-0.28	-0.43	-0.17	-0.18	-0.20	-1.98	-2.06	-1.43	-0.77	-1.43	-0.85	1.01	0.68
November	0.36	0.20	-0.57	-0.52	1.93	1.71	0.93	0.85	-0.96	-0.50	-2.21	-1.48	-0.53	-0.43
December	0.36	0.15	0.57	0.38	0.11	0.10	1.28	1.40	-0.61	-0.45	1.03	0.88	-0.13	-0.09
Spring	0.87	0.15	-0.04	-0.01	-0.50	-0.13	-1.98	-0.66	-0.68	-0.20	0.46	0.12	-0.18	-0.03
Summer	1.04	0.10	-0.86	-0.06	-1.14	-0.19	0.75	0.11	0.29	0.03	0.11	0.01	-1.85	-0.16
Fall	0.01	0.01	-1.03	-0.24	0.71	0.21	-0.44	-0.28	-1.28	-0.39	-3.64	-0.72	0.62	0.17
Winter	0.15	0.06	-0.32	-0.08	0.29	0.17	1.28	0.77	0.43	0.18	0.32	0.13	-0.09	-0.03
Annual	0.57	0.04	-0.50	-0.08	0.43	0.06	-0.35	-0.10	-0.64	-0.08	-1.25	-0.19	-0.44	-0.07

Monthly, seasonal and annual precipitation trends for G18 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	1.11	0.36	-0.61	-0.28	-0.04	-0.03	0.53	0.29	0.93	0.46	-0.57	-0.37	-0.84	-0.55
February	-0.15	-0.07	0.82	0.29	1.18	0.55	0.13	0.14	-1.18	-0.36	-0.57	-0.15	0.44	0.24
March	0.80	0.15	-0.21	-0.09	-0.36	-0.10	0.40	0.16	0.29	0.07	0.64	0.25	-0.44	-0.33
April	-0.59	-0.08	0.71	0.16	-1.89	-0.47	-1.68	-0.47	-0.96	-0.32	-0.04	-0.06	-0.26	-0.10
May	0.57	0.12	-0.36	-0.14	-1.11	-0.35	-2.29	-1.09	-1.28	-0.51	-1.78	-0.47	0.04	0.04
June	2.13	0.34	-1.39	-0.26	-1.61	-0.38	0.40	0.08	1.61	0.39	0.93	0.23	0.31	0.09
July	0.41	0.03	-0.96	-0.15	-0.18	-0.02	0.09	0.01	1.32	0.13	-0.64	-0.03	0.40	0.03
August	0.45	0.04	1.75	0.13	-0.96	-0.05	1.10	0.10	-0.21	-0.01	-1.93	-0.10	0.26	0.00
September	-0.90	-0.12	0.29	0.05	0.32	0.08	0.53	0.09	0.07	0.01	-0.36	-0.07	0.57	0.11
October	-0.57	-0.15	-0.25	-0.11	0.11	0.07	-0.26	-0.33	-1.36	-0.50	-1.07	-0.33	1.41	0.72
November	0.00	0.00	-0.61	-0.26	0.89	0.55	0.18	0.17	-1.07	-0.60	-1.93	-0.93	-0.71	-0.26
December	-0.66	-0.22	1.21	0.69	0.00	-0.01	0.71	0.29	-0.86	-0.54	0.96	0.45	-1.45	-0.58
Spring	0.10	0.03	-0.50	-0.09	-2.11	-0.31	-1.41	-0.53	-1.46	-0.31	-0.68	-0.10	-0.26	-0.05
Summer	2.02	0.13	-0.71	-0.07	-1.14	-0.10	0.09	0.02	1.11	0.11	-0.14	-0.02	0.40	0.08
Fall	-0.80	-0.10	-0.39	-0.10	0.39	0.11	0.31	0.11	-0.96	-0.20	-2.36	-0.38	1.23	0.22
Winter	0.00	0.00	0.54	0.14	0.29	0.11	0.31	0.12	-0.61	-0.18	0.36	0.10	-0.62	-0.25
Annual	-0.10	0.00	0.11	0.02	-0.07	0.00	-0.57	-0.09	-1.61	-0.14	-1.46	-0.09	0.04	0.01

Monthly, seasonal and annual precipitation trends for N14 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.38	-0.12	-0.96	-0.66	-0.29	-0.14	-0.18	-0.20	0.89	0.79	-0.61	-0.38	-0.22	-0.12
February	0.27	0.09	0.18	0.08	0.25	0.16	0.84	0.56	1.21	0.53	-0.93	-0.46	0.97	0.82
March	0.41	0.13	-0.46	-0.14	0.39	0.19	0.40	0.28	0.21	0.10	1.71	0.60	-0.57	-0.32
April	0.31	0.11	0.21	0.07	0.64	0.53	-2.64	-1.40	-0.86	-0.54	-0.71	-0.37	0.00	0.04
May	0.50	0.16	-0.18	-0.07	-1.36	-0.68	-1.45	-0.74	-0.14	-0.08	-1.46	-0.41	-1.63	-0.73
June	1.29	0.30	-0.21	-0.09	-1.46	-0.61	0.84	0.42	0.46	0.14	0.96	0.25	-1.59	-0.47
July	0.41	0.04	-1.39	-0.20	-0.18	0.00	0.13	0.03	0.21	0.02	-0.11	-0.01	-0.13	-0.01
August	0.15	0.01	1.25	0.05	-0.57	-0.01	1.06	0.04	-1.03	-0.03	-2.28	-0.07	-0.22	-0.01
September	-0.64	-0.11	0.18	0.04	-1.18	-0.22	0.40	0.09	1.00	0.17	-1.00	-0.19	0.88	0.13
October	-0.59	-0.28	-0.39	-0.22	-0.21	-0.16	-1.94	-1.96	-1.46	-0.75	-1.39	-0.79	1.01	0.65
November	0.36	0.21	-0.61	-0.47	1.93	1.61	0.93	0.81	-0.93	-0.51	-2.21	-1.36	-0.57	-0.48
December	0.36	0.16	0.57	0.37	0.21	0.10	1.37	1.37	-0.75	-0.41	1.03	0.89	-0.09	-0.03
Spring	0.80	0.14	-0.14	-0.03	-0.46	-0.13	-1.98	-0.64	-0.64	-0.17	0.50	0.14	-0.09	-0.02
Summer	1.01	0.10	-0.79	-0.07	-1.07	-0.17	0.84	0.11	0.25	0.03	0.18	0.01	-1.72	-0.15
Fall	0.10	0.01	-0.93	-0.21	0.71	0.21	-0.35	-0.23	-1.25	-0.39	-3.53	-0.71	0.57	0.19
Winter	0.17	0.05	-0.32	-0.09	0.29	0.20	1.28	0.73	0.46	0.22	0.29	0.10	0.00	0.00
Annual	0.62	0.04	-0.46	-0.08	0.43	0.08	-0.31	-0.11	-0.71	-0.07	-1.28	-0.18	-0.40	-0.07

Monthly, seasonal and annual precipitation trends for N14 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	1.13	0.36	-0.61	-0.27	-0.04	-0.02	0.62	0.22	0.86	0.47	-0.54	-0.34	-0.97	-0.59
February	-0.17	-0.07	0.75	0.29	1.18	0.56	0.09	0.14	-1.21	-0.32	-0.46	-0.11	0.48	0.26
March	0.71	0.14	-0.21	-0.12	-0.46	-0.13	0.35	0.18	0.21	0.09	0.71	0.28	-0.40	-0.31
April	-0.57	-0.07	0.57	0.13	-1.96	-0.43	-1.63	-0.44	-1.00	-0.28	-0.04	-0.04	-0.26	-0.09
May	0.59	0.11	-0.39	-0.14	-1.11	-0.33	-2.34	-1.07	-1.28	-0.48	-1.75	-0.44	0.09	0.04
June	2.09	0.32	-1.43	-0.24	-1.64	-0.36	0.31	0.07	1.61	0.37	0.82	0.20	0.40	0.09
July	0.52	0.03	-1.00	-0.13	-0.04	-0.01	0.00	0.00	1.36	0.12	-0.39	-0.02	0.18	0.02
August	0.43	0.03	1.93	0.12	-1.11	-0.06	1.01	0.09	-0.25	-0.01	-1.89	-0.09	0.04	0.00
September	-0.97	-0.12	0.39	0.05	0.36	0.07	0.62	0.08	0.18	0.01	-0.29	-0.07	0.57	0.13
October	-0.48	-0.13	-0.32	-0.12	0.25	0.09	-0.26	-0.29	-1.28	-0.45	-1.07	-0.34	1.37	0.69
November	0.10	0.02	-0.68	-0.23	0.93	0.49	0.22	0.17	-1.07	-0.56	-1.96	-0.86	-0.62	-0.29
December	-0.66	-0.20	1.21	0.67	-0.04	-0.01	0.75	0.29	-0.86	-0.56	1.00	0.47	-1.41	-0.59
Spring	0.10	0.01	-0.50	-0.09	-2.21	-0.31	-1.41	-0.49	-1.39	-0.28	-0.54	-0.11	-0.35	-0.05
Summer	1.92	0.13	-0.68	-0.06	-1.25	-0.10	0.18	0.01	1.07	0.10	-0.14	-0.01	0.44	0.07
Fall	-0.73	-0.08	-0.36	-0.07	0.29	0.10	0.35	0.12	-0.96	-0.19	-2.36	-0.34	1.23	0.23
Winter	0.03	0.02	0.57	0.16	0.21	0.10	0.31	0.18	-0.57	-0.15	0.43	0.11	-0.62	-0.21
Annual	-0.06	0.00	0.04	0.01	-0.07	-0.01	-0.66	-0.09	-1.57	-0.13	-1.28	-0.08	0.04	0.02

Monthly, seasonal and annual precipitation trends for N15 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.41	-0.15	-1.03	-0.61	-0.64	-0.26	-0.31	-0.16	0.82	0.90	-0.29	-0.24	-0.09	-0.09
February	-0.08	-0.01	-0.04	-0.08	0.36	0.28	0.97	0.57	1.39	0.77	-0.79	-0.47	0.62	0.66
March	0.31	0.12	-0.68	-0.31	-0.07	-0.04	0.26	0.14	-0.04	-0.03	1.25	0.51	-0.57	-0.31
April	0.36	0.12	-0.21	-0.11	0.82	0.57	-2.25	-1.40	-1.25	-0.62	-0.64	-0.31	0.09	0.05
May	0.62	0.16	-0.29	-0.13	-1.07	-0.55	-1.32	-0.69	-0.14	-0.04	-1.96	-0.54	-1.63	-0.59
June	0.94	0.29	-0.14	-0.11	-1.11	-0.53	0.57	0.12	0.54	0.16	0.82	0.19	-1.15	-0.47
July	0.24	0.03	-1.28	-0.13	0.00	-0.02	0.00	0.00	0.18	0.02	-0.43	-0.03	-0.18	-0.01
August	0.06	0.00	0.82	0.03	-1.07	-0.02	1.19	0.05	-1.50	-0.03	-1.93	-0.05	-0.22	-0.01
September	-0.69	-0.15	-0.04	-0.01	-1.11	-0.27	0.31	0.08	0.86	0.24	-0.89	-0.17	0.79	0.15
October	-0.92	-0.32	-0.89	-0.42	-0.21	-0.12	-1.94	-2.19	-1.39	-0.78	-1.39	-0.70	0.66	0.51
November	0.10	0.06	-0.68	-0.45	1.82	1.67	1.10	0.91	-1.00	-0.59	-2.14	-1.24	-0.88	-0.61
December	0.03	0.03	0.79	0.65	0.32	0.13	1.23	1.26	-0.57	-0.52	1.00	0.95	-0.22	-0.15
Spring	0.92	0.12	-0.54	-0.12	-0.61	-0.17	-1.68	-0.64	-0.61	-0.18	0.18	0.05	-0.26	-0.05
Summer	0.83	0.08	-0.54	-0.03	-0.96	-0.15	0.53	0.08	0.29	0.03	-0.07	0.00	-1.50	-0.12
Fall	-0.36	-0.06	-1.11	-0.38	0.86	0.31	-0.53	-0.27	-1.11	-0.28	-3.75	-0.72	0.35	0.07
Winter	-0.01	0.00	0.00	0.01	0.21	0.12	1.28	0.65	0.36	0.25	0.21	0.13	0.00	-0.03
Annual	0.06	0.01	-0.96	-0.15	0.46	0.06	-0.48	-0.14	-0.39	-0.05	-1.43	-0.21	-0.48	-0.15

Monthly, seasonal and annual precipitation trends for N15 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	1.18	0.36	-0.57	-0.26	0.11	0.08	0.71	0.40	0.89	0.43	-0.64	-0.27	-0.93	-0.57
February	-0.41	-0.13	0.96	0.28	1.28	0.51	0.18	0.11	-1.07	-0.33	-0.32	-0.09	0.22	0.15
March	0.90	0.20	-0.54	-0.19	-0.54	-0.21	0.40	0.19	0.25	0.05	0.57	0.17	-0.48	-0.26
April	-0.27	-0.04	0.18	0.08	-2.14	-0.53	-1.45	-0.38	-1.03	-0.42	0.00	0.01	-0.13	-0.04
May	0.57	0.08	-0.57	-0.19	-0.75	-0.25	-2.42	-1.11	-1.14	-0.39	-1.82	-0.54	0.40	0.08
June	2.06	0.32	-1.53	-0.28	-1.36	-0.33	0.09	0.02	1.53	0.36	0.61	0.15	0.71	0.11
July	0.36	0.03	-0.82	-0.13	-0.32	-0.04	-0.04	-0.01	1.25	0.12	-0.43	-0.03	0.44	0.05
August	0.45	0.03	2.07	0.14	-1.28	-0.07	1.19	0.10	-0.29	-0.02	-1.82	-0.09	0.31	0.02
September	-1.08	-0.14	0.25	0.06	0.39	0.08	0.26	0.04	0.00	0.02	-0.07	-0.01	0.66	0.12
October	-0.45	-0.12	-0.64	-0.23	0.21	0.07	-0.26	-0.14	-1.43	-0.39	-0.93	-0.32	0.97	0.76
November	-0.31	-0.07	-0.50	-0.20	0.89	0.44	0.31	0.32	-1.03	-0.67	-1.86	-0.94	-0.88	-0.37
December	-0.55	-0.22	1.39	0.67	-0.14	-0.05	0.84	0.31	-0.89	-0.56	0.96	0.43	-1.76	-0.73
Spring	0.17	0.03	-1.00	-0.15	-2.11	-0.33	-1.41	-0.46	-1.28	-0.27	-0.68	-0.14	-0.44	-0.12
Summer	1.85	0.12	-0.75	-0.07	-0.89	-0.08	0.09	0.01	0.96	0.10	-0.11	-0.01	0.79	0.09
Fall	-0.97	-0.12	-0.64	-0.16	0.39	0.09	0.44	0.14	-1.03	-0.20	-2.21	-0.39	0.97	0.19
Winter	-0.22	-0.03	0.71	0.20	0.14	0.09	0.22	0.19	-0.36	-0.13	0.32	0.09	-0.48	-0.20
Annual	-0.52	-0.02	-0.32	-0.04	-0.39	-0.04	-0.66	-0.11	-1.43	-0.13	-1.43	-0.11	-0.13	-0.02

Temperature

Monthly, seasonal and annual temperature trends for G03 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.23	0.07	1.21	0.03	0.71	0.01	0.22	0.01	0.89	0.02	1.61	0.04	1.76	0.05
February	3.93	0.06	1.50	0.03	0.96	0.02	0.40	0.01	0.14	0.01	1.89	0.05	2.29	0.06
March	3.62	0.05	0.50	0.01	-0.64	-0.01	0.66	0.03	1.25	0.03	2.71	0.05	2.07	0.06
April	4.18	0.07	0.61	0.01	1.86	0.03	1.59	0.04	1.11	0.02	0.46	0.01	2.56	0.05
May	3.62	0.04	0.61	0.01	1.68	0.04	0.40	0.02	2.50	0.05	3.82	0.07	3.00	0.07
June	3.30	0.03	1.43	0.02	1.28	0.02	0.75	0.02	2.03	0.04	3.32	0.06	4.32	0.15
July	5.39	0.05	3.03	0.03	-0.21	0.00	1.41	0.03	3.75	0.05	4.32	0.07	3.88	0.11
August	5.42	0.06	2.75	0.03	1.36	0.02	1.72	0.03	3.85	0.05	4.71	0.08	4.19	0.10
September	5.42	0.06	1.78	0.02	-0.54	-0.01	0.48	0.01	2.82	0.04	5.10	0.08	4.14	0.09
October	4.28	0.06	2.07	0.04	1.11	0.03	3.04	0.07	3.64	0.08	3.28	0.09	2.95	0.08
November	4.65	0.06	-1.32	-0.03	3.00	0.06	0.22	0.01	2.00	0.04	2.78	0.07	4.72	0.13
December	3.53	0.05	0.46	0.01	2.60	0.05	1.72	0.04	3.89	0.07	2.18	0.04	3.13	0.09
Spring	5.18	0.05	0.61	0.01	1.64	0.03	1.54	0.03	2.14	0.03	4.35	0.05	3.22	0.06
Summer	5.77	0.05	2.57	0.03	1.61	0.02	1.59	0.03	4.32	0.05	5.21	0.07	4.54	0.13
Fall	6.14	0.06	1.46	0.02	2.43	0.03	1.98	0.03	3.75	0.06	4.50	0.08	4.50	0.10
Winter	5.51	0.06	1.93	0.02	2.25	0.03	0.53	0.01	2.14	0.03	3.14	0.05	4.01	0.07
Annual	6.84	0.05	2.11	0.02	2.71	0.02	1.85	0.03	4.17	0.04	5.57	0.06	5.38	0.09

Monthly, seasonal and annual temperature trends for G03 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.32	0.04	2.46	0.04	1.61	0.01	1.59	0.02	2.75	0.04	4.28	0.06	3.31	0.06
February	5.11	0.05	0.79	0.01	2.36	0.03	1.85	0.02	2.75	0.03	4.03	0.06	3.75	0.06
March	3.76	0.04	0.96	0.01	0.82	0.01	0.75	0.01	4.32	0.04	3.96	0.06	4.01	0.07
April	4.44	0.04	1.75	0.02	1.78	0.02	1.19	0.02	4.50	0.05	3.89	0.05	4.41	0.07
May	4.70	0.04	2.93	0.02	2.36	0.02	1.32	0.02	3.46	0.04	5.07	0.07	4.85	0.07
June	4.70	0.03	2.53	0.03	2.32	0.02	1.41	0.02	4.78	0.04	5.32	0.07	4.67	0.10
July	6.44	0.06	4.75	0.04	4.25	0.03	2.91	0.03	5.35	0.06	5.99	0.08	5.86	0.12
August	6.56	0.06	5.35	0.05	3.03	0.02	3.66	0.03	5.50	0.06	5.82	0.09	5.95	0.11
September	6.35	0.06	3.60	0.03	0.57	0.00	1.45	0.02	5.00	0.05	5.57	0.08	5.20	0.09
October	5.91	0.06	2.57	0.03	1.14	0.01	2.20	0.03	4.25	0.05	5.00	0.07	4.50	0.08
November	5.30	0.04	1.32	0.02	2.93	0.03	-0.93	-0.01	3.32	0.05	2.82	0.03	5.16	0.10
December	4.63	0.04	2.82	0.03	2.07	0.03	1.32	0.02	4.96	0.06	4.46	0.06	4.98	0.07
Spring	5.32	0.04	2.39	0.02	2.50	0.02	1.45	0.02	4.71	0.05	5.21	0.06	5.07	0.07
Summer	6.75	0.05	5.46	0.04	4.17	0.03	3.39	0.03	6.17	0.06	6.46	0.08	5.82	0.11
Fall	7.05	0.05	3.78	0.03	2.39	0.01	1.19	0.01	5.32	0.05	5.85	0.06	6.13	0.09
Winter	6.09	0.04	3.32	0.02	3.03	0.02	2.34	0.02	4.21	0.04	5.00	0.06	4.98	0.07
Annual	7.35	0.05	5.00	0.03	4.35	0.02	2.95	0.02	6.17	0.05	6.71	0.06	6.04	0.08

Monthly, seasonal and annual temperature trends for G12 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.23	0.07	1.18	0.03	0.64	0.01	0.22	0.01	0.89	0.02	1.61	0.04	1.76	0.05
February	3.93	0.06	1.50	0.03	0.96	0.02	0.40	0.01	0.14	0.01	1.89	0.05	2.29	0.06
March	3.60	0.05	0.50	0.01	-0.71	-0.01	0.66	0.03	1.25	0.03	2.75	0.05	2.16	0.06
April	4.18	0.07	0.64	0.01	1.82	0.03	1.59	0.04	1.11	0.02	0.43	0.01	2.60	0.05
May	3.62	0.04	0.61	0.01	1.68	0.04	0.40	0.02	2.50	0.05	3.82	0.07	3.04	0.07
June	3.32	0.03	1.43	0.02	1.25	0.02	0.71	0.02	2.03	0.04	3.35	0.06	4.32	0.15
July	5.42	0.05	3.00	0.03	-0.25	0.00	1.41	0.02	3.75	0.05	4.35	0.07	3.84	0.11
August	5.44	0.06	2.75	0.03	1.36	0.02	1.76	0.03	3.85	0.05	4.71	0.08	4.19	0.11
September	5.46	0.06	1.78	0.02	-0.61	-0.01	0.44	0.01	2.82	0.04	5.14	0.07	4.14	0.09
October	4.28	0.06	2.07	0.04	1.11	0.03	3.09	0.07	3.64	0.07	3.28	0.09	2.95	0.08
November	4.67	0.06	-1.36	-0.03	3.03	0.06	0.31	0.01	2.03	0.04	2.85	0.07	4.72	0.13
December	3.51	0.05	0.50	0.01	2.60	0.05	1.76	0.04	3.85	0.08	2.14	0.04	3.13	0.09
Spring	5.14	0.05	0.57	0.01	1.64	0.03	1.54	0.03	2.14	0.03	4.39	0.05	3.22	0.06
Summer	5.79	0.05	2.60	0.03	1.64	0.02	1.59	0.02	4.32	0.05	5.25	0.07	4.54	0.13
Fall	6.16	0.06	1.46	0.02	2.50	0.03	1.94	0.03	3.78	0.06	4.46	0.08	4.54	0.10
Winter	5.49	0.06	1.93	0.02	2.18	0.03	0.57	0.01	2.14	0.03	3.07	0.05	4.01	0.07
Annual	6.84	0.05	2.07	0.02	2.71	0.02	1.85	0.02	4.14	0.04	5.57	0.06	5.38	0.09

Monthly, seasonal and annual temperature trends for G18 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.39	0.04	2.57	0.04	1.64	0.02	1.76	0.02	2.75	0.04	4.35	0.06	3.26	0.06
February	5.02	0.05	0.89	0.01	2.32	0.03	1.90	0.02	2.75	0.03	4.03	0.06	3.70	0.06
March	3.74	0.04	0.96	0.01	0.86	0.01	0.71	0.02	4.25	0.04	3.96	0.06	3.97	0.07
April	4.44	0.04	1.71	0.02	1.89	0.02	1.19	0.02	4.50	0.05	3.85	0.05	4.36	0.07
May	4.74	0.04	2.96	0.02	2.18	0.02	1.37	0.02	3.50	0.04	5.10	0.07	4.89	0.07
June	4.72	0.03	2.53	0.03	2.32	0.02	1.32	0.01	4.82	0.04	5.28	0.07	4.67	0.10
July	6.47	0.06	4.82	0.04	4.21	0.03	2.82	0.04	5.35	0.06	6.03	0.08	5.86	0.13
August	6.56	0.06	5.46	0.05	2.96	0.03	3.79	0.03	5.50	0.06	5.78	0.09	5.86	0.11
September	6.40	0.06	3.60	0.03	0.39	0.00	1.63	0.02	4.96	0.05	5.53	0.08	5.20	0.09
October	5.84	0.06	2.64	0.03	1.00	0.01	2.20	0.03	4.35	0.05	5.10	0.07	4.54	0.08
November	5.32	0.04	1.32	0.02	2.82	0.03	-0.79	-0.01	3.28	0.05	2.78	0.03	5.16	0.10
December	4.60	0.04	2.82	0.03	2.07	0.03	1.41	0.02	5.07	0.06	4.46	0.06	4.98	0.07
Spring	5.32	0.04	2.32	0.02	2.46	0.02	1.37	0.02	4.67	0.05	5.21	0.06	5.03	0.07
Summer	6.82	0.05	5.32	0.04	4.14	0.03	3.44	0.03	6.14	0.06	6.49	0.08	5.77	0.11
Fall	7.05	0.05	3.78	0.03	2.25	0.01	1.19	0.01	5.32	0.04	5.78	0.06	6.13	0.09
Winter	6.02	0.04	3.35	0.03	3.00	0.02	2.42	0.02	4.28	0.04	5.03	0.06	5.03	0.07
Annual	7.38	0.05	4.96	0.03	4.35	0.02	2.82	0.02	6.14	0.05	6.71	0.06	6.08	0.08

Monthly, seasonal and annual temperature trends for G18 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.25	0.07	1.18	0.03	0.64	0.01	0.22	0.01	0.89	0.02	1.61	0.04	1.76	0.05
February	3.95	0.06	1.46	0.03	0.96	0.02	0.40	0.01	0.14	0.01	1.89	0.05	2.29	0.06
March	3.62	0.05	0.50	0.01	-0.71	-0.01	0.66	0.03	1.28	0.03	2.71	0.05	2.16	0.06
April	4.18	0.07	0.61	0.01	1.86	0.03	1.63	0.04	1.11	0.02	0.43	0.01	2.60	0.05
May	3.60	0.04	0.61	0.01	1.68	0.04	0.40	0.02	2.50	0.05	3.82	0.07	3.04	0.07
June	3.32	0.03	1.43	0.02	1.25	0.02	0.71	0.02	2.03	0.04	3.35	0.06	4.32	0.15
July	5.42	0.05	3.00	0.03	-0.25	0.00	1.41	0.03	3.75	0.05	4.35	0.07	3.88	0.11
August	5.44	0.06	2.75	0.03	1.36	0.02	1.72	0.03	3.85	0.05	4.71	0.08	4.19	0.11
September	5.46	0.06	1.78	0.02	-0.61	-0.01	0.44	0.01	2.82	0.04	5.17	0.07	4.14	0.09
October	4.28	0.06	2.07	0.04	1.11	0.03	3.04	0.07	3.64	0.07	3.28	0.09	2.95	0.08
November	4.67	0.06	-1.32	-0.03	3.03	0.06	0.31	0.01	2.03	0.04	2.85	0.07	4.72	0.13
December	3.51	0.05	0.50	0.01	2.57	0.05	1.76	0.04	3.82	0.08	2.14	0.04	3.13	0.09
Spring	5.14	0.05	0.57	0.01	1.64	0.03	1.59	0.03	2.14	0.03	4.39	0.05	3.22	0.06
Summer	5.79	0.05	2.60	0.03	1.64	0.02	1.59	0.03	4.32	0.05	5.25	0.07	4.54	0.13
Fall	6.16	0.06	1.46	0.02	2.46	0.03	1.94	0.03	3.78	0.06	4.50	0.08	4.54	0.10
Winter	5.51	0.06	1.96	0.02	2.18	0.03	0.62	0.01	2.14	0.03	3.03	0.05	4.01	0.07
Annual	6.86	0.05	2.07	0.02	2.71	0.02	1.85	0.02	4.07	0.04	5.57	0.06	5.38	0.09

Monthly, seasonal and annual temperature trends for G18 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.42	0.04	2.53	0.04	1.64	0.02	1.76	0.02	2.78	0.04	4.39	0.06	3.26	0.06
February	5.00	0.05	0.96	0.01	2.28	0.03	1.90	0.02	2.75	0.03	4.03	0.06	3.70	0.06
March	3.76	0.04	0.93	0.01	0.86	0.01	0.71	0.02	4.28	0.04	3.93	0.06	3.97	0.07
April	4.46	0.04	1.75	0.02	1.89	0.02	1.19	0.02	4.50	0.05	3.85	0.05	4.36	0.07
May	4.74	0.04	3.00	0.02	2.14	0.02	1.37	0.02	3.50	0.04	5.10	0.07	4.89	0.07
June	4.72	0.03	2.53	0.03	2.32	0.02	1.37	0.01	4.82	0.04	5.28	0.07	4.67	0.10
July	6.47	0.06	4.82	0.04	4.21	0.03	2.82	0.04	5.35	0.06	6.03	0.08	5.86	0.13
August	6.56	0.06	5.46	0.05	2.96	0.03	3.79	0.03	5.50	0.07	5.78	0.09	5.86	0.11
September	6.40	0.06	3.60	0.03	0.43	0.00	1.63	0.02	4.96	0.05	5.53	0.08	5.20	0.09
October	5.84	0.05	2.64	0.03	1.00	0.01	2.20	0.03	4.35	0.05	5.10	0.07	4.54	0.08
November	5.32	0.04	1.32	0.02	2.82	0.03	-0.79	-0.01	3.32	0.05	2.78	0.03	5.16	0.10
December	4.63	0.04	2.82	0.03	2.07	0.03	1.41	0.02	5.07	0.06	4.46	0.06	4.98	0.07
Spring	5.32	0.04	2.32	0.02	2.46	0.02	1.37	0.02	4.71	0.05	5.21	0.06	5.03	0.07
Summer	6.82	0.05	5.32	0.04	4.14	0.03	3.44	0.03	6.14	0.06	6.49	0.08	5.77	0.11
Fall	7.05	0.05	3.75	0.03	2.32	0.01	1.19	0.01	5.32	0.04	5.78	0.06	6.13	0.09
Winter	6.00	0.04	3.35	0.03	3.00	0.02	2.42	0.02	4.28	0.04	5.03	0.06	5.03	0.07
Annual	7.38	0.05	4.96	0.03	4.32	0.02	2.82	0.02	6.14	0.05	6.71	0.06	6.08	0.08

Monthly, seasonal and annual temperature trends for N14 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.23	0.07	1.21	0.03	0.71	0.01	0.22	0.01	0.93	0.02	1.61	0.04	1.76	0.05
February	3.93	0.06	1.50	0.03	0.96	0.02	0.40	0.01	0.14	0.01	1.89	0.05	2.29	0.06
March	3.62	0.05	0.50	0.01	-0.64	-0.01	0.66	0.03	1.25	0.03	2.71	0.05	2.12	0.06
April	4.18	0.06	0.64	0.01	1.89	0.03	1.63	0.04	1.11	0.02	0.46	0.01	2.42	0.05
May	3.62	0.05	0.61	0.01	1.68	0.04	0.40	0.02	2.50	0.05	3.82	0.07	3.04	0.07
June	3.30	0.03	1.43	0.02	1.28	0.02	0.75	0.02	2.03	0.04	3.32	0.06	4.32	0.16
July	5.39	0.05	3.03	0.03	-0.25	0.00	1.41	0.03	3.75	0.06	4.35	0.07	3.88	0.11
August	5.42	0.06	2.75	0.03	1.36	0.02	1.76	0.03	3.85	0.05	4.71	0.09	4.19	0.11
September	5.42	0.06	1.75	0.02	-0.54	-0.01	0.48	0.01	2.82	0.05	5.10	0.08	4.14	0.09
October	4.30	0.06	2.07	0.05	1.18	0.03	3.04	0.07	3.68	0.08	3.28	0.09	3.00	0.08
November	4.65	0.06	-1.32	-0.03	3.00	0.06	0.22	0.01	2.00	0.04	2.82	0.07	4.72	0.13
December	3.53	0.05	0.46	0.01	2.60	0.05	1.76	0.04	3.89	0.07	2.14	0.04	3.13	0.09
Spring	5.21	0.05	0.57	0.01	1.61	0.03	1.63	0.03	2.14	0.03	4.35	0.05	3.26	0.06
Summer	5.81	0.05	2.57	0.03	1.61	0.02	1.59	0.03	4.32	0.05	5.21	0.07	4.54	0.13
Fall	6.12	0.06	1.53	0.02	2.43	0.03	1.94	0.03	3.75	0.05	4.50	0.08	4.54	0.10
Winter	5.51	0.06	1.93	0.02	2.21	0.03	0.53	0.01	2.14	0.03	3.10	0.05	4.01	0.06
Annual	6.82	0.05	2.11	0.02	2.68	0.02	1.85	0.03	4.25	0.04	5.60	0.06	5.38	0.09

Monthly, seasonal and annual temperature trends for N14 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.51	0.05	2.03	0.03	1.89	0.02	1.23	0.02	2.43	0.04	4.32	0.06	3.04	0.05
February	4.72	0.05	0.18	0.00	1.93	0.03	0.93	0.01	2.96	0.04	4.03	0.07	3.66	0.06
March	3.72	0.04	0.29	0.00	0.21	0.00	0.48	0.01	3.89	0.05	4.35	0.07	3.79	0.07
April	4.25	0.05	1.50	0.02	1.53	0.02	0.79	0.01	3.82	0.05	4.10	0.05	3.66	0.06
May	4.28	0.03	3.10	0.03	2.07	0.02	0.84	0.02	3.25	0.05	5.42	0.07	4.45	0.08
June	4.39	0.03	2.96	0.03	2.07	0.02	1.28	0.02	3.82	0.04	5.50	0.07	4.63	0.11
July	6.07	0.06	4.50	0.04	3.28	0.03	2.95	0.04	5.25	0.06	5.74	0.09	5.82	0.12
August	6.40	0.06	4.85	0.05	2.71	0.02	3.84	0.04	5.10	0.07	5.89	0.09	5.47	0.10
September	6.40	0.06	3.50	0.04	0.64	0.00	1.50	0.02	4.92	0.05	5.46	0.08	5.03	0.08
October	5.98	0.06	2.71	0.03	1.25	0.01	1.85	0.03	4.25	0.04	5.14	0.08	4.36	0.08
November	5.14	0.05	1.53	0.02	3.10	0.04	-1.59	-0.01	3.50	0.05	3.78	0.05	4.81	0.09
December	4.25	0.04	2.60	0.03	2.64	0.03	0.57	0.01	4.71	0.06	5.07	0.06	4.58	0.07
Spring	4.95	0.04	1.57	0.02	1.68	0.02	0.97	0.01	4.00	0.05	5.25	0.07	4.72	0.07
Summer	6.79	0.05	5.07	0.04	3.57	0.03	3.79	0.03	5.53	0.06	6.57	0.08	5.51	0.11
Fall	7.00	0.05	3.71	0.03	2.53	0.02	1.06	0.01	5.21	0.04	5.78	0.07	5.69	0.08
Winter	5.65	0.04	2.32	0.02	3.18	0.03	1.50	0.01	4.57	0.05	5.03	0.06	4.85	0.06
Annual	7.10	0.05	3.96	0.03	3.50	0.02	2.29	0.02	5.74	0.05	6.57	0.07	5.86	0.08

Monthly, seasonal and annual temperature trends for N15 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.21	0.07	1.21	0.03	0.61	0.01	0.26	0.01	0.86	0.02	1.57	0.05	1.81	0.05
February	3.90	0.06	1.39	0.03	0.96	0.02	0.35	0.01	0.07	0.00	1.93	0.05	2.25	0.06
March	3.62	0.05	0.54	0.01	-0.57	-0.01	0.71	0.03	1.36	0.03	2.93	0.05	2.20	0.06
April	4.16	0.06	0.82	0.01	1.89	0.03	1.41	0.04	1.03	0.02	0.57	0.02	2.51	0.05
May	3.69	0.05	0.79	0.01	1.68	0.04	0.79	0.02	2.60	0.05	3.89	0.07	2.95	0.07
June	3.48	0.04	1.28	0.02	1.14	0.02	0.75	0.02	2.11	0.04	3.50	0.07	4.23	0.15
July	5.56	0.06	2.85	0.03	-0.25	0.00	1.37	0.03	3.85	0.06	4.46	0.07	3.88	0.11
August	5.53	0.06	2.82	0.03	1.39	0.02	1.76	0.03	3.93	0.05	4.82	0.09	4.23	0.10
September	5.49	0.06	2.07	0.02	-0.54	-0.01	0.31	0.01	3.03	0.05	5.28	0.08	4.23	0.09
October	4.39	0.06	2.21	0.05	1.14	0.03	3.17	0.07	3.75	0.08	3.25	0.09	3.00	0.08
November	4.70	0.06	-1.32	-0.03	3.14	0.06	0.13	0.00	1.96	0.04	3.00	0.07	4.85	0.13
December	3.53	0.05	0.32	0.01	2.43	0.04	1.76	0.04	3.78	0.08	2.14	0.04	3.17	0.09
Spring	5.30	0.05	0.82	0.01	1.61	0.03	1.72	0.04	2.21	0.03	4.42	0.05	3.35	0.06
Summer	5.93	0.05	2.71	0.03	1.64	0.02	1.54	0.03	4.28	0.05	5.17	0.07	4.50	0.12
Fall	6.16	0.06	1.39	0.02	2.50	0.03	1.85	0.03	3.89	0.05	4.42	0.08	4.63	0.10
Winter	5.39	0.06	1.96	0.02	2.21	0.03	0.57	0.01	2.03	0.03	3.07	0.05	4.01	0.06
Annual	6.96	0.05	2.32	0.02	2.64	0.02	1.90	0.02	4.25	0.04	5.71	0.06	5.47	0.09

Monthly, seasonal and annual temperature trends for N15 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	4.32	0.04	2.43	0.04	1.61	0.01	1.45	0.02	2.57	0.03	4.14	0.06	3.31	0.06
February	5.16	0.05	0.82	0.01	2.39	0.03	2.25	0.02	2.89	0.03	3.96	0.06	3.53	0.05
March	3.74	0.03	1.28	0.01	0.86	0.01	0.84	0.02	4.28	0.04	4.10	0.06	4.06	0.08
April	4.35	0.04	1.89	0.02	1.82	0.02	0.97	0.02	4.46	0.05	4.00	0.05	4.50	0.06
May	4.81	0.04	3.03	0.03	2.60	0.03	1.68	0.02	3.43	0.05	5.17	0.07	4.94	0.07
June	4.56	0.03	2.60	0.03	2.39	0.02	1.59	0.02	4.85	0.04	5.32	0.07	4.85	0.10
July	6.37	0.06	4.78	0.04	4.39	0.03	3.09	0.04	5.46	0.06	5.99	0.08	5.91	0.12
August	6.58	0.06	5.42	0.05	2.75	0.02	3.66	0.03	5.53	0.06	5.89	0.09	5.95	0.10
September	6.40	0.06	3.64	0.03	0.93	0.01	1.50	0.02	5.03	0.05	5.67	0.08	5.33	0.09
October	5.88	0.06	2.68	0.03	1.21	0.01	2.16	0.03	4.21	0.04	5.00	0.07	4.54	0.08
November	5.46	0.04	1.14	0.02	3.21	0.03	-0.93	-0.01	3.18	0.05	3.00	0.04	5.25	0.09
December	4.51	0.04	2.75	0.03	2.14	0.03	1.41	0.02	4.89	0.06	4.53	0.06	4.98	0.07
Spring	5.11	0.04	2.71	0.02	2.50	0.02	1.45	0.02	4.53	0.05	5.28	0.06	5.07	0.07
Summer	6.70	0.05	5.53	0.04	4.35	0.02	3.57	0.03	6.14	0.06	6.42	0.08	5.91	0.11
Fall	7.12	0.05	3.82	0.03	2.75	0.02	1.23	0.01	5.17	0.04	5.92	0.06	6.00	0.09
Winter	6.12	0.04	3.18	0.02	3.14	0.03	2.16	0.02	4.00	0.04	5.07	0.06	4.98	0.07
Annual	7.35	0.04	4.78	0.03	4.25	0.02	3.04	0.02	6.17	0.05	6.71	0.06	6.04	0.08

Total Discharge

Monthly, seasonal and annual discharge trends for G03 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q.	Z	Q
January	-0.10	0.00	-1.18	-0.09	0.29	0.02	0.53	0.05	0.00	0.00	-1.75	-0.12	-0.66	-0.04
February	0.15	0.01	-0.71	-0.04	0.25	0.02	0.93	0.09	0.54	0.03	-2.03	-0.11	0.31	0.03
March	0.10	0.00	-0.57	-0.03	0.29	0.03	0.53	0.05	0.00	0.00	-0.54	-0.02	-0.66	-0.03
April	0.06	0.00	-0.18	0.00	0.64	0.02	-2.07	-0.08	-1.32	-0.04	-1.07	-0.04	-0.13	0.00
May	0.17	0.00	0.07	0.00	-0.82	-0.02	-2.07	-0.06	-1.18	-0.02	-1.11	-0.01	-0.66	-0.01
June	0.92	0.01	-0.32	0.00	-1.61	-0.01	-1.32	-0.01	-0.39	0.00	-0.71	0.00	-1.23	-0.01
July	0.69	0.00	-0.54	0.00	-1.50	0.00	-1.15	-0.01	-0.46	0.00	-0.79	0.00	-1.28	0.00
August	0.59	0.00	-0.54	0.00	-1.53	0.00	-1.15	0.00	-0.54	0.00	-0.86	0.00	-1.28	0.00
September	0.08	0.00	-0.39	0.00	-1.46	0.00	-1.06	0.00	0.00	0.00	-0.86	0.00	-1.28	0.00
October	-0.78	0.00	-0.39	0.00	-0.96	0.00	-2.34	0.00	-1.14	0.00	-2.18	0.00	-0.31	0.00
November	-0.10	0.00	-0.93	-0.01	0.61	0.01	-0.62	-0.02	-1.50	-0.02	-3.68	-0.03	0.22	0.00
December	-0.57	-0.02	0.18	0.03	1.00	0.05	0.66	0.05	-1.93	-0.10	-1.21	-0.05	-0.44	-0.02
Spring	0.13	0.00	-0.07	0.00	-0.14	-0.01	-0.79	-0.04	-0.32	-0.01	-0.75	-0.02	-0.31	-0.01
Summer	0.76	0.00	-0.36	0.00	-1.64	-0.01	-1.23	-0.01	-0.36	0.00	-0.75	0.00	-1.19	-0.01
Fall	-0.29	0.00	-1.07	0.00	0.04	0.00	-0.75	-0.01	-1.46	-0.01	-3.82	-0.01	-0.04	0.00
Winter	-0.10	0.00	-1.14	-0.05	1.00	0.03	0.66	0.05	-0.25	-0.02	-2.14	-0.09	-0.48	-0.02
Annual	-0.10	0.00	-1.21	-0.02	0.46	0.01	0.18	0.00	-0.61	-0.01	-1.82	-0.03	-0.44	-0.02

Monthly, seasonal and annual discharge trends for G03 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	0.62	0.02	-0.32	-0.02	0.79	0.03	1.10	0.07	-0.32	-0.03	-1.89	-0.08	-1.01	-0.03
February	-0.22	-0.01	0.07	0.01	1.14	0.05	0.53	0.04	-1.46	-0.06	-1.03	-0.06	-0.40	-0.02
March	0.08	0.00	-0.61	-0.01	0.50	0.01	0.18	0.01	-1.11	-0.02	-0.29	-0.01	-1.45	-0.05
April	-0.50	-0.01	0.11	0.00	-1.68	-0.04	-1.63	-0.04	-1.68	-0.04	-0.50	-0.01	-1.19	-0.02
May	-0.15	0.00	-0.57	-0.01	-2.03	-0.02	-2.16	-0.05	-1.86	-0.04	-2.07	-0.02	-0.93	-0.01
June	1.04	0.00	-1.21	-0.01	-2.96	-0.01	-1.41	-0.01	-1.14	-0.01	-1.75	-0.01	-0.79	0.00
July	0.92	0.00	-1.25	0.00	-2.36	0.00	-1.15	0.00	-1.28	0.00	-1.71	0.00	-0.66	0.00
August	1.08	0.00	-1.14	0.00	-2.46	0.00	-1.06	0.00	-1.25	0.00	-1.71	0.00	-0.66	0.00
September	0.55	0.00	-1.36	0.00	-2.32	0.00	-0.93	0.00	-1.43	0.00	-1.82	0.00	-0.53	0.00
October	-0.87	0.00	-0.25	0.00	-0.14	0.00	-0.75	0.00	-1.71	0.00	-1.78	0.00	-0.40	0.00
November	-0.99	-0.01	-0.54	-0.01	0.29	0.00	0.18	0.00	-1.46	-0.01	-2.82	-0.01	0.93	0.00
December	-1.48	-0.04	0.21	0.01	0.00	0.00	0.88	0.04	-1.61	-0.07	-1.57	-0.04	-0.40	-0.01
Spring	-0.41	0.00	-0.14	-0.01	-0.64	-0.01	-1.10	-0.03	-2.18	-0.04	-1.00	-0.02	-1.10	-0.02
Summer	1.01	0.00	-1.25	0.00	-2.78	-0.01	-1.37	0.00	-1.25	0.00	-1.75	0.00	-0.71	0.00
Fall	-1.13	0.00	-0.71	0.00	0.29	0.00	0.13	0.00	-1.61	0.00	-3.10	0.00	0.71	0.00
Winter	-0.45	-0.01	-0.25	-0.01	1.03	0.03	0.44	0.03	-1.25	-0.03	-1.36	-0.04	-0.79	-0.03
Annual	-0.57	0.00	-0.50	0.00	0.29	0.00	-0.22	0.00	-2.00	-0.02	-1.89	-0.02	-1.45	-0.02

Monthly, seasonal and annual discharge trends for G12 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.24	0.00	-1.00	-0.04	0.25	0.01	0.22	0.01	-0.07	0.00	-1.93	-0.05	-0.75	-0.02
February	-0.06	0.00	-0.89	-0.02	0.39	0.01	0.88	0.04	0.64	0.01	-2.18	-0.06	0.13	0.00
March	-0.17	0.00	-0.89	-0.01	0.43	0.01	0.48	0.02	0.04	0.00	-0.71	-0.01	-0.84	-0.02
April	0.01	0.00	-0.18	0.00	0.50	0.01	-2.12	-0.04	-1.36	-0.02	-1.21	-0.02	-0.13	0.00
May	0.15	0.00	-0.11	0.00	-0.79	-0.01	-1.81	-0.02	-1.11	-0.01	-1.68	-0.01	-0.62	-0.01
June	1.11	0.00	-0.68	0.00	-1.53	-0.01	-0.97	-0.01	-0.36	0.00	-0.82	0.00	-1.32	-0.01
July	0.97	0.00	-0.68	0.00	-1.53	0.00	-0.93	0.00	-0.29	0.00	-0.79	0.00	-1.37	0.00
August	0.59	0.00	-0.50	0.00	-1.64	0.00	-0.93	0.00	-0.32	0.00	-0.96	0.00	-1.32	0.00
September	-0.15	0.00	-0.50	0.00	-1.36	0.00	-0.75	0.00	-0.11	0.00	-1.32	0.00	-1.37	0.00
October	-1.15	0.00	-0.86	0.00	-0.93	0.00	-2.38	0.00	-1.00	0.00	-2.21	0.00	-0.62	0.00
November	-0.31	0.00	-1.00	-0.01	0.29	0.00	-0.71	-0.01	-1.46	-0.01	-3.89	-0.01	0.00	0.00
December	-0.73	-0.01	0.04	0.00	0.71	0.01	0.57	0.01	-1.89	-0.04	-1.53	-0.02	-0.57	0.00
Spring	0.01	0.00	-0.75	0.00	-0.14	0.00	-1.01	-0.01	-0.61	0.00	-1.03	-0.01	-0.31	-0.01
Summer	0.94	0.00	-0.57	0.00	-1.50	0.00	-1.01	0.00	-0.36	0.00	-0.89	0.00	-1.28	0.00
Fall	-0.34	0.00	-1.03	0.00	0.04	0.00	-0.88	0.00	-1.43	0.00	-3.93	0.00	-0.48	0.00
Winter	-0.27	0.00	-0.96	-0.02	0.93	0.01	0.44	0.01	-0.43	-0.01	-2.46	-0.04	-0.31	-0.01
Annual	-0.20	0.00	-1.07	-0.01	0.36	0.00	0.00	0.00	-0.82	0.00	-2.36	-0.01	-0.57	-0.01

Monthly, seasonal and annual discharge trends for G12 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	0.43	0.01	-0.25	-0.01	0.57	0.01	1.06	0.03	-0.54	-0.01	-2.21	-0.03	-0.93	-0.02
February	-0.52	-0.01	0.00	0.00	1.07	0.02	0.57	0.02	-1.53	-0.02	-1.28	-0.02	-0.53	-0.01
March	0.10	0.00	-0.75	-0.01	0.89	0.01	0.00	0.00	-1.32	-0.01	-0.54	-0.01	-1.41	-0.02
April	-0.59	0.00	0.14	0.00	-1.43	-0.02	-1.28	-0.01	-1.89	-0.02	-0.68	-0.01	-1.28	-0.01
May	-0.17	0.00	-0.64	0.00	-1.89	-0.01	-2.20	-0.02	-2.00	-0.02	-2.21	-0.01	-1.01	-0.01
June	1.13	0.00	-1.21	0.00	-2.68	-0.01	-1.10	0.00	-1.25	0.00	-1.68	0.00	-0.57	0.00
July	1.13	0.00	-1.39	0.00	-2.11	0.00	-0.57	0.00	-1.18	0.00	-1.57	0.00	-0.62	0.00
August	1.13	0.00	-0.93	0.00	-2.25	0.00	-0.62	0.00	-1.18	0.00	-1.64	0.00	-0.62	0.00
September	0.22	0.00	-1.14	0.00	-2.36	0.00	-0.26	0.00	-0.93	0.00	-1.61	0.00	-0.44	0.00
October	-1.06	0.00	-0.57	0.00	-0.14	0.00	-0.66	0.00	-1.68	0.00	-1.93	0.00	-0.40	0.00
November	-1.22	0.00	-1.00	0.00	0.21	0.00	0.13	0.00	-1.93	-0.01	-3.35	-0.01	0.53	0.00
December	-1.53	-0.02	0.14	0.00	0.00	0.00	0.75	0.01	-1.57	-0.02	-1.86	-0.01	-0.53	0.00
Spring	-0.55	0.00	-0.50	0.00	-0.39	0.00	-0.93	-0.01	-2.39	-0.02	-1.32	-0.01	-0.93	-0.01
Summer	1.25	0.00	-1.36	0.00	-2.43	0.00	-0.97	0.00	-1.36	0.00	-1.68	0.00	-0.62	0.00
Fall	-1.06	0.00	-1.07	0.00	0.00	0.00	-0.22	0.00	-2.03	0.00	-3.78	0.00	0.48	0.00
Winter	-0.45	0.00	-0.36	0.00	0.79	0.01	0.48	0.01	-1.53	-0.02	-1.82	-0.02	-0.93	-0.01
Annual	-0.69	0.00	-0.46	0.00	0.29	0.00	-0.13	0.00	-2.07	-0.01	-2.39	-0.01	-1.54	-0.01

Monthly, seasonal and annual discharge trends for G18 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.17	0.00	-1.11	-0.02	0.25	0.00	0.26	0.01	-0.07	0.00	-2.00	-0.02	-0.71	-0.01
February	0.01	0.00	-0.93	-0.01	0.43	0.01	0.97	0.02	0.61	0.01	-2.11	-0.03	0.22	0.00
March	-0.15	0.00	-0.82	-0.01	0.57	0.01	0.40	0.01	0.00	0.00	-0.75	-0.01	-0.88	-0.01
April	0.06	0.00	-0.25	0.00	0.57	0.01	-2.16	-0.02	-1.39	-0.01	-1.18	-0.01	-0.09	0.00
May	0.13	0.00	-0.07	0.00	-0.86	-0.01	-1.90	-0.01	-1.07	-0.01	-1.50	0.00	-0.66	0.00
June	1.15	0.00	-0.71	0.00	-1.64	0.00	-0.97	0.00	-0.25	0.00	-0.75	0.00	-1.32	0.00
July	1.01	0.00	-0.64	0.00	-1.57	0.00	-0.93	0.00	-0.25	0.00	-0.68	0.00	-1.45	0.00
August	0.64	0.00	-0.46	0.00	-1.64	0.00	-0.93	0.00	-0.36	0.00	-0.89	0.00	-1.37	0.00
September	-0.13	0.00	-0.50	0.00	-1.36	0.00	-0.66	0.00	-0.07	0.00	-1.32	0.00	-1.37	0.00
October	-1.13	0.00	-0.71	0.00	-1.03	0.00	-2.34	0.00	-1.00	0.00	-2.28	0.00	-0.71	0.00
November	-0.24	0.00	-0.96	0.00	0.29	0.00	-0.57	0.00	-1.53	0.00	-3.93	-0.01	-0.09	0.00
December	-0.66	0.00	0.11	0.00	0.86	0.01	0.48	0.01	-1.96	-0.02	-1.46	-0.01	-0.48	0.00
Spring	0.10	0.00	-0.36	0.00	-0.14	0.00	-1.01	-0.01	-0.61	0.00	-0.96	-0.01	-0.40	0.00
Summer	0.97	0.00	-0.54	0.00	-1.53	0.00	-0.88	0.00	-0.39	0.00	-0.71	0.00	-1.32	0.00
Fall	-0.31	0.00	-1.11	0.00	0.07	0.00	-0.79	0.00	-1.50	0.00	-3.82	0.00	-0.40	0.00
Winter	-0.10	0.00	-0.96	-0.01	0.96	0.01	0.40	0.01	-0.43	0.00	-2.32	-0.02	-0.40	0.00
Annual	-0.27	0.00	-1.00	0.00	0.43	0.00	0.00	0.00	-0.89	0.00	-2.25	-0.01	-0.57	0.00

Monthly, seasonal and annual discharge trends for G18 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	0.48	0.00	-0.32	0.00	0.79	0.01	1.15	0.01	-0.46	-0.01	-2.11	-0.02	-0.97	-0.01
February	-0.41	0.00	-0.04	0.00	1.07	0.01	0.66	0.01	-1.64	-0.01	-1.21	-0.01	-0.57	-0.01
March	0.10	0.00	-0.75	-0.01	0.86	0.01	0.00	0.00	-1.28	-0.01	-0.43	0.00	-1.54	-0.01
April	-0.62	0.00	0.18	0.00	-1.50	-0.01	-1.28	-0.01	-1.93	-0.01	-0.61	0.00	-1.23	-0.01
May	-0.10	0.00	-0.75	0.00	-1.86	-0.01	-2.07	-0.01	-1.96	-0.01	-2.14	-0.01	-1.06	0.00
June	1.13	0.00	-1.25	0.00	-2.75	0.00	-1.10	0.00	-1.21	0.00	-1.53	0.00	-0.57	0.00
July	1.22	0.00	-1.32	0.00	-2.00	0.00	-0.48	0.00	-1.14	0.00	-1.43	0.00	-0.62	0.00
August	1.25	0.00	-1.07	0.00	-2.07	0.00	-0.40	0.00	-1.11	0.00	-1.53	0.00	-0.53	0.00
September	0.15	0.00	-1.07	0.00	-2.21	0.00	-0.18	0.00	-0.82	0.00	-1.50	0.00	-0.48	0.00
October	-1.06	0.00	-0.57	0.00	-0.07	0.00	-0.66	0.00	-1.64	0.00	-2.03	0.00	-0.44	0.00
November	-1.18	0.00	-0.93	0.00	0.18	0.00	0.09	0.00	-2.03	0.00	-3.28	0.00	0.48	0.00
December	-1.46	-0.01	0.14	0.00	0.04	0.00	0.79	0.01	-1.61	-0.01	-1.82	-0.01	-0.48	0.00
Spring	-0.50	0.00	-0.46	0.00	-0.39	0.00	-1.01	-0.01	-2.28	-0.01	-1.25	0.00	-0.97	-0.01
Summer	1.25	0.00	-1.18	0.00	-2.46	0.00	-0.84	0.00	-1.21	0.00	-1.57	0.00	-0.57	0.00
Fall	-1.04	0.00	-1.11	0.00	0.04	0.00	-0.18	0.00	-2.03	0.00	-3.64	0.00	0.57	0.00
Winter	-0.41	0.00	-0.32	0.00	0.89	0.01	0.48	0.00	-1.57	-0.01	-1.64	-0.01	-0.88	0.00
Annual	-0.66	0.00	-0.50	0.00	0.29	0.00	-0.09	0.00	-2.03	-0.01	-2.28	0.00	-1.54	0.00

Monthly, seasonal and annual discharge trends for N14 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.01	0.00	-1.14	-0.08	0.32	0.02	0.62	0.05	-0.04	0.00	-1.78	-0.09	-0.66	-0.03
February	0.20	0.01	-0.71	-0.03	0.25	0.01	1.06	0.07	0.57	0.03	-2.11	-0.09	0.35	0.02
March	0.01	0.00	-0.54	-0.03	0.25	0.01	0.62	0.04	0.11	0.00	-0.29	-0.01	-0.66	-0.03
April	0.10	0.00	-0.07	0.00	0.57	0.02	-2.16	-0.06	-1.32	-0.03	-1.00	-0.03	-0.04	0.00
May	0.10	0.00	0.11	0.00	-0.75	-0.02	-2.20	-0.04	-1.14	-0.02	-0.82	-0.01	-0.53	-0.01
June	0.87	0.00	-0.36	0.00	-1.46	-0.01	-1.32	-0.01	-0.32	0.00	-0.64	0.00	-1.28	-0.01
July	0.80	0.00	-0.46	0.00	-1.36	0.00	-1.28	0.00	-0.36	0.00	-0.71	0.00	-1.23	0.00
August	0.66	0.00	-0.43	0.00	-1.36	0.00	-1.23	0.00	-0.32	0.00	-0.68	0.00	-1.23	0.00
September	0.10	0.00	-0.32	0.00	-1.36	0.00	-1.06	0.00	0.07	0.00	-0.89	0.00	-1.23	0.00
October	-0.76	0.00	-0.39	0.00	-0.86	0.00	-2.20	0.00	-1.18	0.00	-2.18	0.00	-0.22	0.00
November	-0.06	0.00	-0.93	-0.01	0.75	0.01	-0.62	-0.01	-1.50	-0.01	-3.68	-0.02	0.26	0.00
December	-0.57	-0.02	0.29	0.01	1.18	0.04	0.53	0.04	-1.86	-0.08	-1.11	-0.03	-0.40	-0.01
Spring	0.20	0.00	-0.11	0.00	0.00	0.00	-0.71	-0.02	-0.36	0.00	-0.54	-0.01	-0.22	-0.01
Summer	0.76	0.00	-0.29	0.00	-1.39	0.00	-1.28	-0.01	-0.29	0.00	-0.75	0.00	-1.28	0.00
Fall	-0.24	0.00	-1.00	0.00	0.11	0.00	-0.66	-0.01	-1.50	-0.01	-3.71	-0.01	0.04	0.00
Winter	0.00	0.00	-1.11	-0.04	1.07	0.03	0.75	0.04	-0.25	-0.01	-2.03	-0.07	-0.48	-0.02
Annual	0.01	0.00	-1.11	-0.01	0.71	0.01	0.18	0.00	-0.57	-0.01	-1.57	-0.02	-0.44	-0.01

Monthly, seasonal and annual discharge trends for N14 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	0.66	0.02	-0.32	-0.01	0.82	0.03	1.15	0.05	-0.36	-0.02	-1.82	-0.06	-1.06	-0.02
February	-0.22	-0.01	0.14	0.01	1.21	0.04	0.44	0.03	-1.53	-0.04	-0.96	-0.04	-0.40	-0.02
March	0.22	0.01	-0.50	-0.01	0.32	0.01	0.18	0.01	-0.93	-0.02	-0.18	-0.01	-1.50	-0.04
April	-0.48	-0.01	0.00	0.00	-1.64	-0.03	-1.45	-0.03	-1.68	-0.03	-0.21	-0.01	-1.15	-0.02
May	-0.13	0.00	-0.57	-0.01	-2.14	-0.02	-2.20	-0.04	-1.82	-0.03	-1.96	-0.02	-0.88	-0.01
June	1.01	0.00	-1.21	-0.01	-2.93	-0.01	-1.37	-0.01	-1.07	-0.01	-1.46	0.00	-0.79	0.00
July	1.01	0.00	-1.32	0.00	-2.46	0.00	-1.10	0.00	-1.21	0.00	-1.53	0.00	-0.62	0.00
August	1.01	0.00	-1.25	0.00	-2.53	0.00	-1.01	0.00	-1.32	0.00	-1.61	0.00	-0.53	0.00
September	0.62	0.00	-1.39	0.00	-2.36	0.00	-0.97	0.00	-1.36	0.00	-1.39	0.00	-0.31	0.00
October	-0.80	0.00	-0.21	0.00	-0.25	0.00	-0.84	0.00	-1.75	0.00	-1.64	0.00	-0.22	0.00
November	-0.94	-0.01	-0.57	0.00	0.32	0.00	0.22	0.00	-1.46	-0.01	-2.75	-0.01	0.79	0.00
December	-1.34	-0.03	0.11	0.01	0.00	0.00	0.79	0.03	-1.57	-0.05	-1.18	-0.03	-0.53	-0.01
Spring	-0.31	0.00	-0.18	0.00	-0.61	-0.01	-1.01	-0.02	-2.11	-0.03	-1.03	-0.01	-1.01	-0.02
Summer	1.01	0.00	-1.21	0.00	-2.89	0.00	-1.37	0.00	-1.14	0.00	-1.53	0.00	-0.71	0.00
Fall	-0.97	0.00	-0.71	0.00	0.32	0.00	0.09	0.00	-1.61	0.00	-3.00	0.00	0.75	0.00
Winter	-0.31	0.00	-0.25	-0.01	1.03	0.02	0.48	0.03	-1.25	-0.02	-1.36	-0.03	-0.66	-0.02
Annual	-0.48	0.00	-0.46	0.00	0.21	0.00	-0.18	0.00	-2.00	-0.01	-1.82	-0.01	-1.37	-0.01

Monthly, seasonal and annual discharge trends for N15 subbasin M6 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	-0.01	0.00	-1.00	-0.06	-0.04	0.00	0.57	0.05	-0.11	-0.01	-1.89	-0.08	-1.01	-0.04
February	-0.13	0.00	-1.00	-0.03	0.21	0.02	0.84	0.06	0.86	0.04	-1.93	-0.07	0.22	0.01
March	0.22	0.00	-0.82	-0.03	0.07	0.00	0.62	0.03	0.14	0.01	-0.50	-0.01	-0.97	-0.03
April	0.24	0.00	-0.50	-0.01	0.25	0.00	-2.12	-0.05	-1.57	-0.03	-0.96	-0.02	0.13	0.01
May	0.08	0.00	-0.21	0.00	-0.82	-0.01	-2.16	-0.04	-1.11	-0.01	-1.46	-0.01	-0.40	-0.01
June	0.73	0.00	-0.96	0.00	-0.86	-0.01	-1.41	-0.01	-0.29	0.00	-0.93	0.00	-1.01	0.00
July	0.41	0.00	-0.89	0.00	-1.03	0.00	-1.32	0.00	-0.21	0.00	-0.79	0.00	-1.06	0.00
August	0.27	0.00	-0.86	0.00	-1.07	0.00	-1.28	0.00	-0.21	0.00	-0.86	0.00	-1.06	0.00
September	-0.03	0.00	-0.82	0.00	-0.89	0.00	-1.19	0.00	0.04	0.00	-0.86	0.00	-1.15	0.00
October	-0.94	0.00	-1.14	0.00	-0.50	0.00	-2.29	0.00	-1.00	0.00	-2.28	0.00	0.00	0.00
November	-0.55	0.00	-1.21	-0.01	0.79	0.01	-0.62	-0.01	-1.36	-0.01	-3.35	-0.02	-0.35	0.00
December	-0.90	-0.02	0.29	0.01	1.00	0.04	0.57	0.04	-1.89	-0.08	-0.93	-0.03	-0.53	-0.02
Spring	0.22	0.00	-1.03	-0.02	-0.11	0.00	-0.84	-0.02	-0.57	-0.01	-0.50	-0.01	-0.44	-0.01
Summer	0.64	0.00	-1.03	0.00	-0.93	0.00	-1.37	0.00	-0.29	0.00	-0.82	0.00	-1.01	0.00
Fall	-0.78	0.00	-1.25	0.00	0.39	0.00	-0.66	-0.01	-1.28	-0.01	-3.53	-0.01	-0.35	0.00
Winter	-0.43	-0.01	-1.14	-0.03	1.11	0.02	0.79	0.04	-0.11	-0.01	-1.89	-0.06	-0.53	-0.03
Annual	-0.48	0.00	-1.50	-0.02	0.79	0.01	0.00	0.00	-0.54	0.00	-1.96	-0.02	-0.66	-0.01

Monthly, seasonal and annual discharge trends for N15 subbasin M8 scenario

	M6		SSP2-4.5						SSP5-8.5					
	Historical		Near Future		Mid Future		Far Future		Near Future		Mid Future		Far Future	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
January	0.57	0.01	-0.18	-0.01	0.71	0.02	1.10	0.05	-0.11	-0.01	-1.68	-0.06	-1.15	-0.04
February	-0.45	-0.01	0.04	0.00	1.03	0.03	0.26	0.02	-1.21	-0.03	-0.75	-0.03	-0.57	-0.02
March	0.38	0.01	-0.71	-0.02	0.18	0.00	0.13	0.01	-1.07	-0.01	-0.39	-0.01	-1.32	-0.04
April	-0.38	0.00	-0.11	0.00	-1.75	-0.03	-1.23	-0.02	-1.82	-0.03	-0.14	0.00	-1.19	-0.01
May	-0.03	0.00	-1.11	-0.01	-2.14	-0.01	-2.25	-0.03	-1.71	-0.02	-2.07	-0.01	-0.88	-0.01
June	0.78	0.00	-1.50	-0.01	-2.68	-0.01	-1.54	-0.01	-1.14	0.00	-1.78	0.00	-0.57	0.00
July	0.78	0.00	-1.46	0.00	-2.53	0.00	-1.28	0.00	-1.14	0.00	-1.71	0.00	-0.40	0.00
August	0.83	0.00	-1.32	0.00	-2.57	0.00	-1.28	0.00	-1.25	0.00	-1.86	0.00	-0.44	0.00
September	0.27	0.00	-1.32	0.00	-2.50	0.00	-1.19	0.00	-1.25	0.00	-1.50	0.00	-0.35	0.00
October	-1.13	0.00	-0.79	0.00	-0.18	0.00	-0.62	0.00	-1.61	0.00	-1.53	0.00	0.26	0.00
November	-1.22	-0.01	-0.79	-0.01	0.68	0.00	0.31	0.00	-1.50	-0.01	-2.68	-0.01	0.44	0.00
December	-1.50	-0.03	0.14	0.00	0.25	0.01	0.75	0.03	-1.71	-0.05	-1.57	-0.02	-0.79	-0.02
Spring	-0.27	0.00	-0.64	-0.01	-0.79	-0.01	-0.75	-0.01	-2.07	-0.02	-0.86	-0.01	-1.01	-0.01
Summer	0.87	0.00	-1.57	0.00	-2.68	0.00	-1.32	0.00	-1.28	0.00	-1.75	0.00	-0.57	0.00
Fall	-1.25	0.00	-1.07	0.00	0.36	0.00	0.09	0.00	-1.53	0.00	-2.85	0.00	0.40	0.00
Winter	-0.62	-0.01	-0.32	-0.01	0.86	0.01	0.31	0.02	-1.07	-0.02	-1.14	-0.02	-1.15	-0.03
Annual	-0.71	0.00	-0.64	0.00	0.18	0.00	-0.04	0.00	-1.78	-0.01	-1.75	-0.01	-1.41	-0.01