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Dısaggregatıon Of Global Clımate Model Data To Create Idf Curves Under Rcp8.5 Scenarıo

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Abstract
Global climate change is one of the most important problems of our age. Its possible harmful effects are flood formation, loss of life and property, severe drought etc. Many studies are carried out to reduce these damages and to limit the impact area. The creation of precipitation intensity-duration-frequency curves (IDF) is one of these studies. These curves are especially used in the design of water structures. IDF curves are usually generated from observed precipitation data. This situation causes these curves to stay away from precipitation changes due to climate change. Therefore, these curves need to be updated under future climate projections. In this study, this problem was emphasized and the IDF curves of Muğla province were tried to be estimated according to the years 2023–2098 under the RCP8.5 scenarios of the HadGEM-ES, GFDL-ESM2M global models with the equivalent quantile matching method.

Keywords: Climate change, climate model, disaggregation, IDF Curves

1. Introduction

The global climate is being seriously damaged day by day, especially due to human-induced effects. These damages affect many areas. Climate change causes the existing balance of nature to deteriorate, causing extreme consequences, especially in conditions of temperature and precipitation. Due to the large number of affected areas, various topics and studies have been carried out on these areas. Studies have been conducted on the effects of global climate change on the environment (Davis et al., 2010; Angelique and Culley 2010), its effects on glaciers (Thompson 2010; Dinar and Mendelssohn 2009), and its regional effects (Brunettia et al., 2003; Abreu and Schönfelda 2003). Some of the studies have been done on climate models and scenarios (Tayşi and Özger, 2021; Giannakopoulos et al., 2009). In this study, it is aimed to predict IDF curves over climate models and scenarios. IDF curves are of great importance for the design phase of water structures. Assuming that the IDF curves are largely created with historical data, it will not be appropriate to use these curves continuously since they cannot accommodate the precipitation change as a result of climate change. Therefore, these curves need to be updated considering climate change. With the help of equivalent quantile matching method, daily precipitation data of climate models (GFDL-ESM2M, HadGEM-ES) were converted into standard-duration precipitation data and IDF curves for the years 2023–2098 were tried to be estimated. In the study conducted for the province of Muğla, the historical data of the province of Muğla and the global climate model prediction data were compared, and it was tried to observe how the climate change could affect the precipitation.

2. Materials and Methods

2.1. Study area

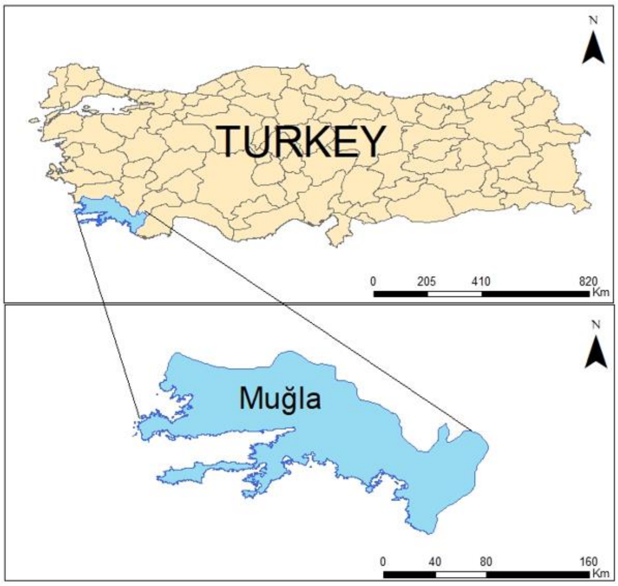

Figure 1. Muğla province location map

Muğla province was chosen as the study area (Figure 1). Muğla is a city with a Mediterranean climate type. In the Mediterranean climate, summer months are generally dry and hot, and winter months are rainy and warm.

2.2 Data

The data used in the study were obtained from the General Directorate of Meteorology. These data are respectively RCP8.5 scenario precipitation data belonging to HadGEM-ES, GFDL-ESM2M global climate models, model historical data belonging to climate models covering the years 1971–2000, and observed precipitation data covering the years 1971–2000 for Muğla province.

2.3 Equidistance Quantile Matching Method

Equidistance quantile matching method is a method used to convert daily maximum precipitation data into sub-daily durations of 5, 10, 15, 30 mins and 1, 2, 6, 12 hours. The steps of the method are as follows.

a) Data in all available data sets are obtained as annual maximum precipitation data.
b) Historical data of climate models, observed precipitation data with standard time periods and future precipitation data of climate models are fitted to the Gumbel distribution and their parameters are found.
c) A linear relationship is obtained between the cumulative distribution function of the historical data sets of climate models and the cumulative distribution function of the observed data.

$$Y_{max,j}^{STN} = a_1 * X_{max}^{GCM} + b_1 \quad (1)$$

d) A linear relationship is obtained between the cumulative distribution function of the future precipitation data of the climate models and the cumulative distribution functions of the historical data of the climate models.

$$Y_{max}^{GCM,FUT} = a_2 * X_{max}^{GCM} + b_2 \quad (2)$$

e) By combining the equations in steps c and d, the following equation is obtained. This equation also performs the disaggregation process.

$$X_{max}^{STN,FUT} = a_1 * \left[\frac{X_{max}^{GCM,FUT} - b_2}{a_2}\right] + b_1 \quad (3)$$

f) In the last step, the disaggregated data is calculated with the Gumbel distribution according to the return periods and curves are drawn (Srivastav vd., 2014).

MATLAB program was used for the calculations in the study.

3. Results and Discussion

In order to test the consistency of the model used in the study and its success in disaggregation, a comparison was made between the observed data and the disaggregated HadGEM-ES and GFDL-ESM2M model historical data.

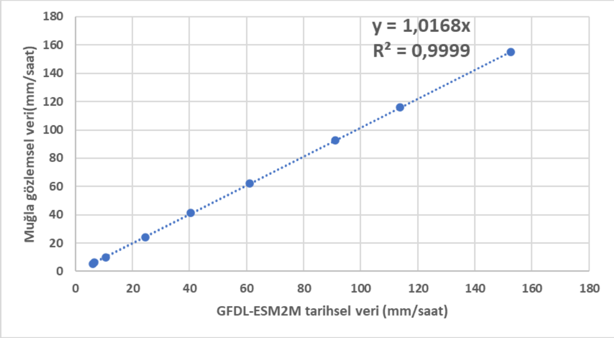

Figure 2. Comparison of disaggregated GFDL-ESM2M model historical data with observed data for a 10-year recurrence interval.

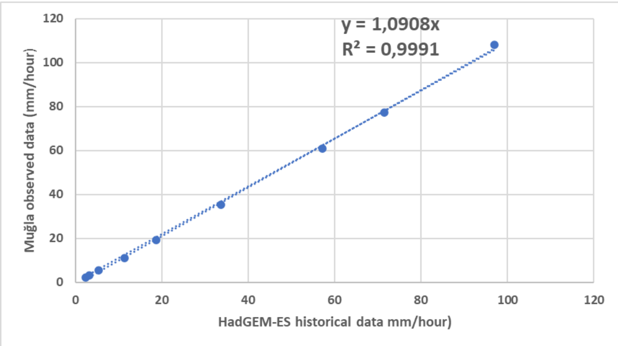

Figure 3. Comparison of disaggregated HadGEM-ES model historical data with observed data for a 10-year recurrence interval

As seen in Figures 2 and 3, the coefficient of determination of $R^2 \approx 1$ was found between the historical data of the disaggregated model and the observed data of Muğla province. It has been seen that the model gives satisfied results in disaggregation.

Table 1. Comparison of disaggregated model's future precipitation data with observed data as % change

HadGEM-ES model RCP8.5 scenario			
Ret. period (yr)	**2**	**5**	**10**
2023-2048	49.8	64.8	72.0
2049-2074	-9.9	6.0	11.9
2075-2098	-2.2	0.9	2.4

GFDL-ESM2M model RCP8.5 scenario			
Ret. period (yr)	**2**	**5**	**10**
2023-2048	-1.2	-11.9	-15.8
2049-2074	-15.9	-27.0	-32.4
2075-2098	-20.0	-25.7	-27.9

As seen in Table 1, for the HadGEM-ES model, precipitation increases by 49 to 72% between 2023 and 2048, and decreases by 10% for the 2-year return period. For 5- and 10-year return periods, a decrease of 6 to 12% is observed between 2049 and 2074. Between 2075 and 2098, while there is a decrease of 2% for the 2-year return period, an increase of 1 and 2%, is predicted for 5- and 10-year return periods, respectively. When the GFDL-ESM2M model is examined, a decrease of 1 to 16% for the years 2023-2048, 15 to 33% for the years 2049-2074, and 20 to 28% for the years 2075-2098 is predicted.

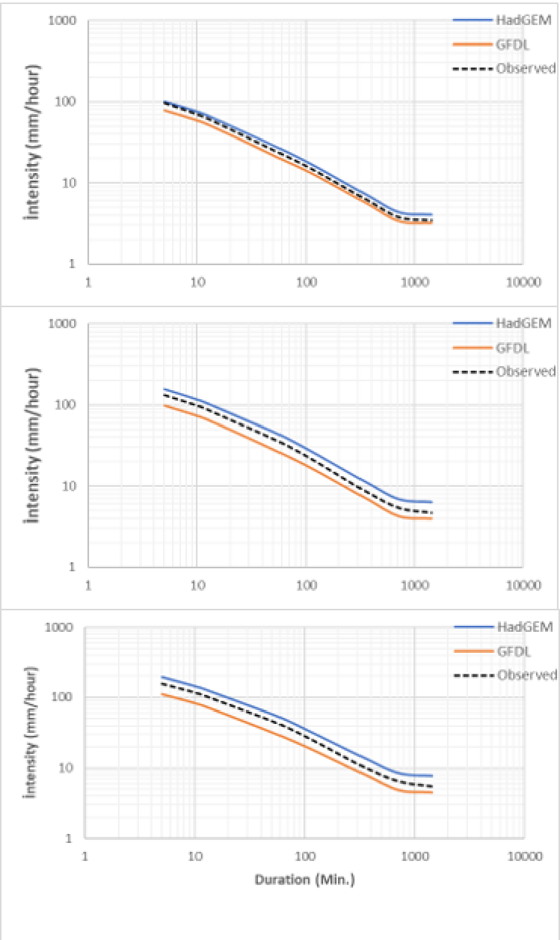

Figure 4. Comparison of the IDF curves derived by the observed precipitation data with those derived from climate models' future predictions for the years 2023-2098 for the return periods of 2-, 5-, and 10-years from top to bottom, respectively.

In Figure 4, a comparison of IDF curves derived from the disaggregated models with those derived from the observed data shows that the HadGEM-ES model has a positive bias and gives higher values than the values derived from the observed data. On the other hand, the GFDL-ESM2M model has a negative bias and gives lower values than the values derived from the observed data.

Figure 5. Percent change of precipitation intensity of climate models' predictions with respect to observed data for 2-, 5- and 10-year return periods from top to bottom, respectively.

When the data in Figure 5 are examined, it is seen that the HadGEM-ES model generally predicts higher values with increased rainfall durations compared to the observed values, while the GFDL-ESM2M model generally predicts lower values with increased rainfall durations compared to the observed values for 2-year return period. There is no such a monotonous trend for the 5- and 10-year return periods for GFDL-ESM2M model.

In the study of Tayşi and Özger (2021), according to the HadGEM-ES model, precipitation will increase for Istanbul, and in the study of Gürkan et al. (2016), there will be a general decrease in precipitation in Turkey in the 2023-2098 period according to the GFDL-ESM2M model. Similar results were observed between the results obtained in this study and some studies in the literature.

4. Results

Since global climate change is one of the most important problems of our age, it is necessary to carry out many studies on this issue that will emphasize the importance of reducing its harmful effects. In this study, scenarios have been produced for the province of Muğla on how global climate change can affect precipitation between 2023 and 2098.

The following results were obtained:

- When the disaggregated data obtained from the HadGEM-ES model is compared with the observed precipitation data, an increase in the range of 5 to 17% is predicted for 2-year return period between 2023 and 2098.
- These predictions of increase become 16 to 26% and 20 to 30% for 5- and 10-year returns periods respectively.
- GFDL-ESM2M model predicts a decrease of 8 to 22%, 15 to 35%, and 20 to 44% for the return periods of 2-, 5-, and 10-years, respectively.

In general, it has been predicted that there will be an increase in precipitation according to the HadGEM-ES model and a decrease in precipitation according to the GFDL-ESM2M model. According to the data obtained from HadGEM-ES model for Muğla province, it is concluded that the existing stormwater infrastructure may become insufficient, which may cause flooding. However, based on the GFDL-ESM2M model, the stormwater infrastructure in Muğla province is expected to be sufficient under the RCP8.5 scenario.

References

Brunettia, M., Buffonib, L., Mangiantic, F., Maugeria, M. and Nannid, T. (2003) 'Temperature, precipitation and extreme events during the last century in Italy',Global and Planetary Change, Vol. 40, pp. 141–149.

Culley, M.R.and Angelique, H. (2010) 'Nuclear power: Renaissance or relapse? Global climate change and long-term three mile island activists' Narratives', American Journal of Community Psychology, Vol. 45 No. 3-4, pp. 231-246

Davis, C.C., Willis, C.G., Primack, R.B., and Miller-Rushing A.J. (2010) 'The importance of phylogeny to the study of phonological response to global climate change', Philosophical Transactions of the Royal Society B-Biological Sciences, Vol. 365 No.1555, pp. 3201–3213

Giannakopoulos, C., Le Sager, P., Bindi, M., Moriondo, M., Kostopoulou, E., and Goodess, C.M. (2009) 'Climatic changes and associated impacts in the Mediterranean resulting from a 2 °C global warming', Global and Planetary Change, Vol. 68 No. 3, pp. 209–224.

Gürkan, H., Arabacı, H., Demircan, M., Eskioğlu, O. , Şensoy, S. & Yazıcı, B. (2016). Temperature and precipitation projections for Turkey according to RCP4.5 and RCP8.5 scenarios based on the GFDL-ESM2M model. (In Turkish) “GFDL-ESM2M Modeli temelinde RCP4.5 ve RCP8.5 senaryolarına göre Türkiye için sıcaklık ve yağış projeksiyonları”. Journal of Geographical Sciences, 14 (2) , 77-88 . DOI: 10.1501/Cogbil_0000000174

Mendelssohn, R.O. and Dinar, A. (2009) 'Climate change and agriculture: An economic analysis of global impacts, adaptation and distributional effects (New Horizons in Environmental Economics)', Publisher(s): Edward Elgar Publishing Ltd, Publication date: 2009, ISBN/ISSN: 9781847206701, 246 p

Schönfeld, J., Zhan, R. andde Abreu, L. (2003) 'Surface and deep water response to rapid climate changes at the Western Iberian Magrin', Global and Planetary Change, Vol. 36, pp. 237–264.

Srivastav, Roshan, Andre Schardong, ve Slobodan Simonovic. 2014. Computerized tool for the Development of Intensity-Duration-Frequency Curves under a Changing Climate: Technical Manual v.1.

Tayşi, H., & Özger, M. (2021). Disaggregation of future GCMs to generate IDF curves for the assessment of urban floods. Journal of Water and Climate Change, 13(2), 684-706. https://doi.org/10.2166/wcc.2021.241

Thompson, L.G. (2010) 'Understanding global climate change: Paleo climate perspective from the world's highest mountains', Proceedings of the American Philosophical, Vol. 154 No. 2, pp. 133-157.