MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
VIETNAM INSTITUTE OF METEOROLOGY HYDROLOGY AND CLIMATE CHANGE

Climate Change Impact on Intensity-Duration-Frequency Curves in Ho Chi Minh city

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2. Data and Method

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1. INTRODUCTION

Rationale

- Unpredictable extreme events increase year by year
  - Heavy rainfall in Hanoi, 2008
  - Heavy rainfall in Quang Ninh, 2015
  - Heavy rainfall in Ho Chi Minh city, 2016

=> Causing flooding, damaging significantly socio-economy.

1. INTRODUCTION

Rationale

How to adapt to natural disaster like heavy rainfall?

- Anticipating partly the frequency and intensity of extreme rainfall events in the future
- Enhancing infrastructure
- New planning and management

=> Rainfall Intensity – Duration – Frequency curve is a conducive tool

1. INTRODUCTION

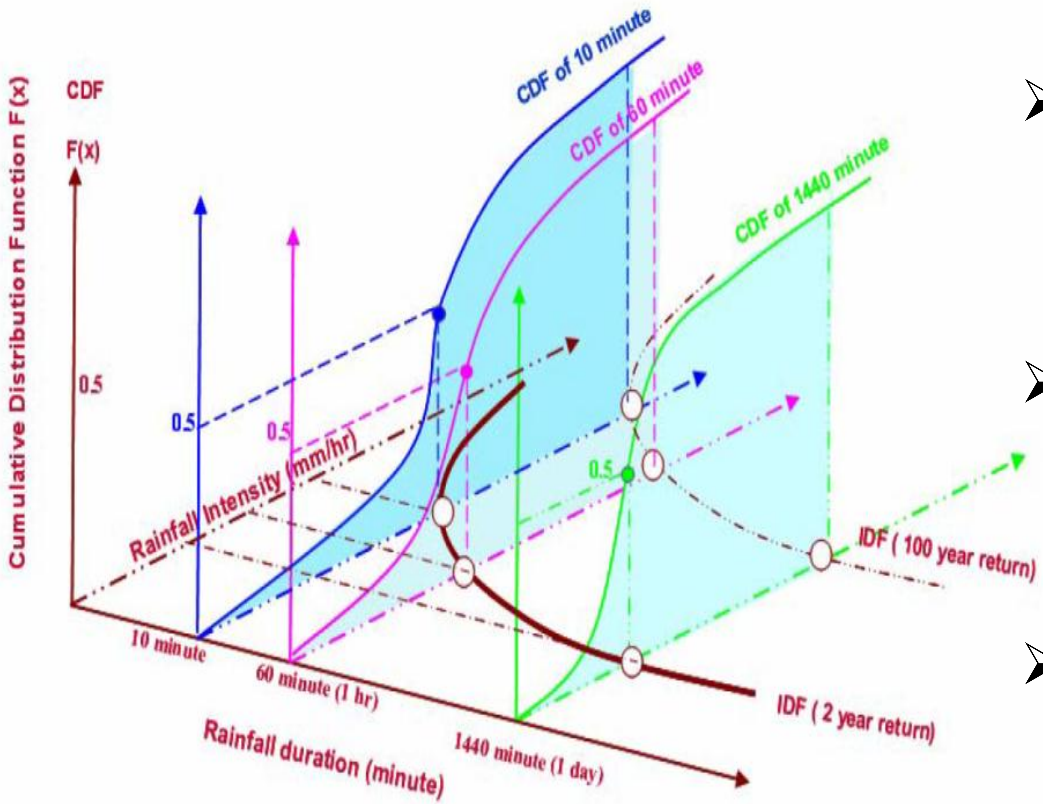
The goal of this research: To examine the impact of climate change on rainfall IDF (intensity-duration-frequency) for Ho Chi Minh city (HCMC), Vietnam.

2 required objectives:

- To downscale rainfall from regional climate model outputs.
- to construct rainfall IDF curves for current as well as future periods.

1. INTRODUCTION

What is Rainfall Intensity - Duration – Frequency relationship?



Le Minh Nhat, 2008

- Expresses the relationship of rainfall intensity in several durations for several return periods.
- A conducive representative for extreme rainfall in short duration over an urban area.
- Required for design of sewer, drainage to serve urban planning and management.

1. INTRODUCTION

Research Area: **Ho Chi Minh city (HCMC)**

- Biggest city of Vietnam, lies on the Mekong River delta.
- Climatology:
  - Annual mean temperature: 26,5 - 27,5°C, the highest temperature is about 28 – 29°C and the lowest temperature is 24 - 26°C.
  - Annual rainfall is from 1600 mm to 2000 mm, rainy season from May to October, the highest rainfall occurs in August, September and October. During the rainy season, there are 4-6 months whose rainfall is above 200mm/month and the dry season has 4–5 months whose rainfall is below 50mm/month.

2. DATA AND METHOD

Information on RCMs

No.	RCM	Organization	Driving GCMs	Resolution, Domain	Vertical level
1	clWRF	NCAR, NCEP, FSL, AFWA, ...	1. NorESM1-M	30 km, 3,5÷27^{o}N and 97,5÷116^{o}E	27
2	PRECIS	Hadley, UK	1. CNRM-CM5 2. GFDL-CM3 3. HadGEM2-ES	25 km, 6,5÷25^{o}N and 99,5÷115^{o}E	19
3	CCAM	CSIRO, Australia	1. ACCESS1-0 2. CCSM4 3. CNRM-CM5 4. GFDL-CM3 5. MPI-ESM-LR 6. NorESM1-M	10 km, 5÷30^{o}N and 98÷115^{o}E	27
4	RegCM	NCAR, USA	1. ACCESS1-0 2. NorESM1-M	20 km, 6,5÷30^{o}N and 99,5÷119,5^{o}E	18

2. DATA AND METHOD

Observation data

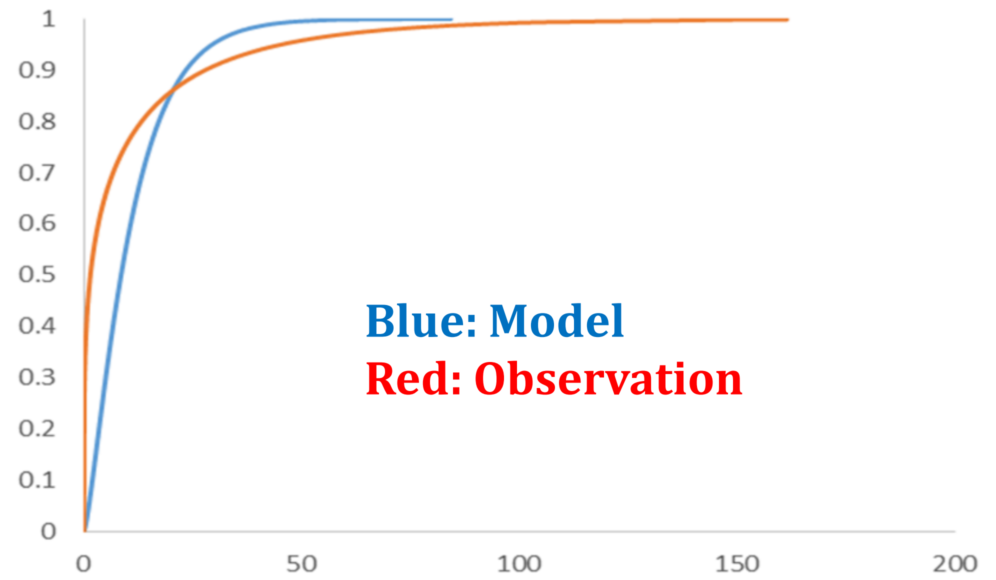
- Daily rainfall at Tan Son Hoa station, used for bias correction
- Rainfall in short duration (15 min, 30 min, 45 min, 1 hr, 1.5 hr, 2 hr, 3 hr, 6 hr and 12 hr), used for construction of rainfall IDF relationship for current climate.

2. DATA AND METHOD

Quantile – Mapping method for bias removal

(Ines 2006, Pinai 2009, Winai 2013, Mishra 2014, ect.)

- **Wet day frequency correction by cut off several very small rainfall value.**
- **Fitting Gamma distribution, matching model CDF into observation CDF**



$$PDF:\ f(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}$$

$$\alpha = \left(\frac{\bar{x}}{\sigma}\right)^2 ; \beta = \frac{\sigma^2}{\bar{x}}$$

$$CDF:\ F(x) = \int_0^x f(t)dt$$

α and β are shape and scale parameters, respectively which are estimated from mean and standard deviation.

2. DATA AND METHOD

Quantile – Mapping method for bias removal

For frequency correction: The cut-off threshold is estimated by:

$$\boldsymbol{Threshold} = \boldsymbol{F}^{-1}_{\boldsymbol{\alpha,\beta-gcm}}\left(\boldsymbol{F}_{\boldsymbol{\alpha,\beta-Obs}}(0.1\boldsymbol{mm})\right)$$

Bias correction for baseline:

$$\boldsymbol{x}^{*}_{\boldsymbol{base}} = \boldsymbol{F}^{-1}_{\boldsymbol{obs}}\left[\boldsymbol{F}_{\boldsymbol{base}}\left(\boldsymbol{x}_{\boldsymbol{RCM}_{\boldsymbol{base}}}\right)\right]$$

Bias correction for future period:

$$\boldsymbol{x}^{*}_{\boldsymbol{fut}} = \boldsymbol{x}_{\boldsymbol{fut}} * \frac{\boldsymbol{F}^{-1}{}_{\boldsymbol{obs}}\left[\boldsymbol{F}_{\boldsymbol{fut}(\boldsymbol{x}_{\boldsymbol{fut}})}\right]}{\boldsymbol{F}^{-1}{}_{\boldsymbol{base}}\left[\boldsymbol{F}_{\boldsymbol{fut}(\boldsymbol{x}_{\boldsymbol{fut}})}\right]}$$

2. DATA AND METHOD

Rainfall IDF construction

➢ **For IDF under current climate:** Using rainfall in short duration (15', 30', 60' ... 1440')

- Fitting gumbel distribution to extreme rainfall for frequency analysis

$$F_d(i) = exp\left(-exp\left(-\frac{i-\mu_d}{\sigma_d}\right)\right)$$

Taking logarit for both 2 sites of equation for 2 times

$$i = \mu_d - \sigma_d * \left(ln\left(-ln\left(1-\frac{1}{T}\right)\right)\right) \qquad T = \frac{1}{1-F}$$

Where: μ_d **and** σ_d are gummbel location and scale parameter, i is rainfall intensity in a given duration, F is quantile and T is return period

2. DATA AND METHOD

Rainfall IDF construction

- From daily bias-corrected model simulation and projection, We use scaling property to temporally downscale daily rainfall into shorter duration

$$I_d = \left(\frac{d}{D}\right)^{-\eta} I_D$$

Menabde (1999), Le Minh Nhat (2008), Van Thanh Van Nguyen (2011), ect.

Where: D is the duration we have, d is expected duration, I is rainfall intensity and η is scaling exponent

- Combine this theory with Gumbel distribution

$$I(d,T) = \frac{\mu_d - \sigma_d * \left(ln\left(-ln\left(1 - \frac{1}{T}\right)\right)\right)}{d^{\eta}}$$

$$\mu_d = (d/D)^{-\eta}\mu_D$$

$$\sigma_d = (d/D)^{-\eta}\sigma_D$$

The scaling exponent η is estimated from method of moment

2. DATA AND METHOD

Ensemble percentiles

- There are many uncertainty sources inside the model as well as from the outside. Therefore, it is indispensable to consider several situations and state of climate in the future with different RCMs and under some GHG Concentration scenarios.
- To synthesize the ensemble simulations, this study is following the approach used in the UK Climate Projections report (Murphy et al. 2009)
  - **The most likely case**: This case is obtained by calculating the 50th percentile of all IDF projection members. The 50th percentile is used here to represent the central value of the distribution, indicating that half of the members are less than or equal to it
  - **High impact case**: This case is the 75th percentile of all IDF projection members. The 75th percentile is to indicate very likely to be less than or very unlikely to be greater than

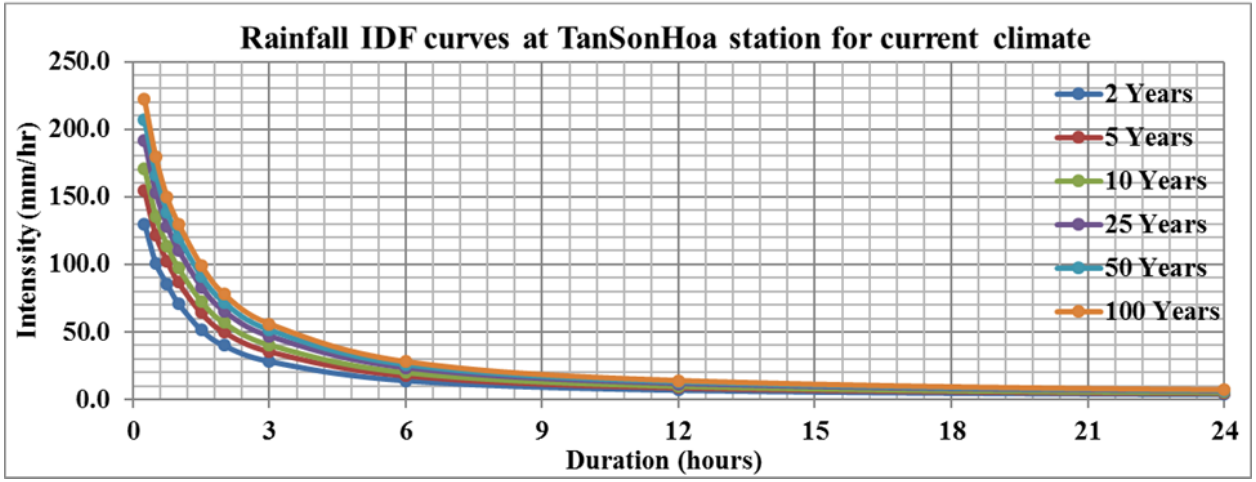
2. DATA AND METHOD

Summarizing all procedures:

1. Interpolating daily rainfall from grid to station using bi-linear interpolation
2. Applying bias correction technique
3. Constructing rainfall IDF under current climate using short duration observation
4. Constructing rainfall IDF under current and future climate using bias-corrected daily rainfall from model simulations and projections
5. Calculating the change of rainfall intensity between future and current climate from model results.
6. Applying these changes to rainfall IDF from observation => rainfall IDF in the future
7. Doing Ensemble of all model projected IDF.

3. RESULTS AND DISCUSSION

Rainfall IDF from short duration observation

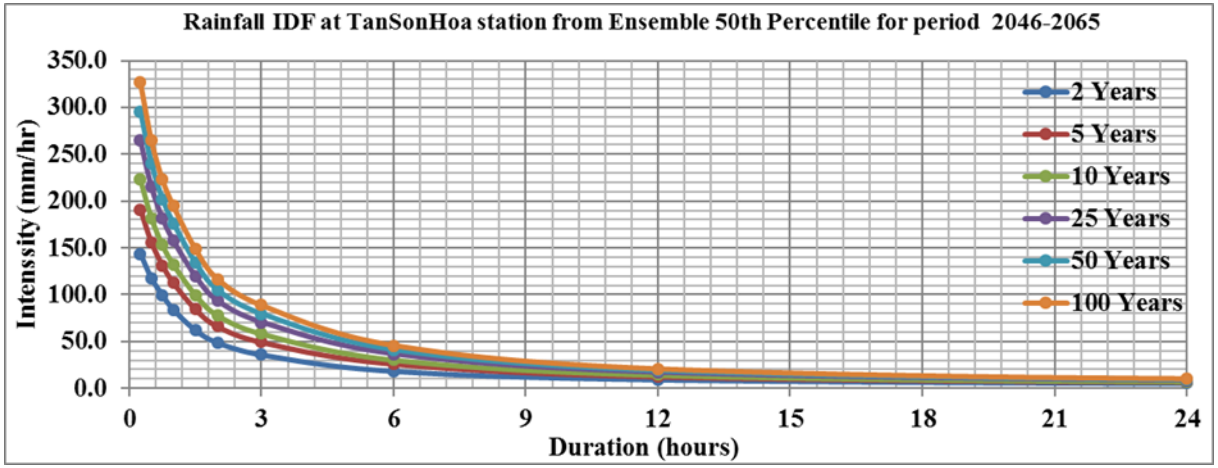


- For 100-years return period (RP): Average rainfall intensity in 15 minutes is 222mm/hour has never been observed in 46 years of observation.
- For 25-years RP: 15 minutes rain fall intensity is 191.5mm/hour. This event occurred 1 time in 2000.
- For 2-years RT: Occurred 25 times in period of 1971-2016.

	15'	30'	45'	60'	90'	2h	3h	6h	12h	24h
2 years	130.0	100.7	85.2	70.9	51.5	40.0	28.3	14.2	7.1	4.0
5 years	154.6	121.8	102.4	86.7	64.3	50.2	35.7	17.9	8.9	4.9
10 years	170.9	135.7	113.8	97.1	72.7	56.9	40.6	20.3	10.2	5.4
25 years	191.5	153.2	128.2	110.4	83.4	65.4	46.8	23.4	11.7	6.2
50 years	206.8	166.3	138.9	120.2	91.3	71.7	51.4	25.7	12.8	6.7
100 years	222.0	179.2	149.5	129.9	99.2	78.0	55.9	28.0	14.0	7.3

3. RESULTS AND DISCUSSION

Most likely case, in the middle of century (2046-2065)



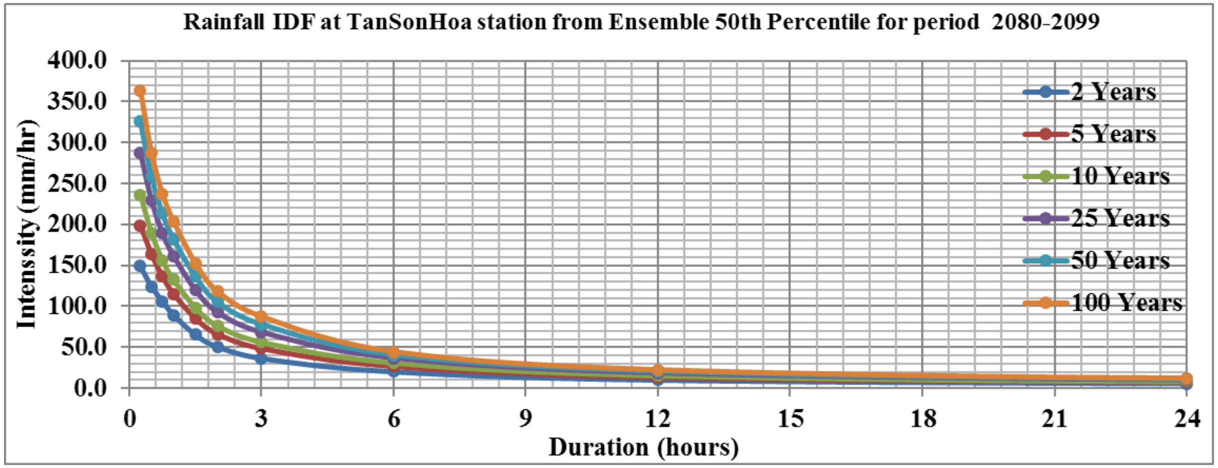
- Increasing in all durations and return periods.
- The increase of longer return periods is higher than shorter return periods.

Change of rainfall IDF (%)

	15'	30'	45'	60'	90'	2h	3h	6h	12h	24h
2 years	11.0	12.3	15.2	21.8	23.9	25.2	26.2	28.7	29.4	29.9
5 years	21.2	22.0	27.2	34.4	36.6	37.0	36.9	45.0	38.0	36.7
10 years	26.4	27.1	33.6	41.5	43.5	43.4	42.5	48.7	39.9	36.2
25 years	32.0	32.2	40.4	48.5	50.4	49.8	48.7	54.4	42.5	38.2
50 years	35.7	35.4	44.5	52.7	54.4	53.7	52.3	57.5	44.1	37.7
100 years	38.8	38.1	48.1	56.4	58.0	57.7	55.8	60.6	45.5	40.1

3. RESULTS AND DISCUSSION

Most likely case, in the end of century (2080-2099)



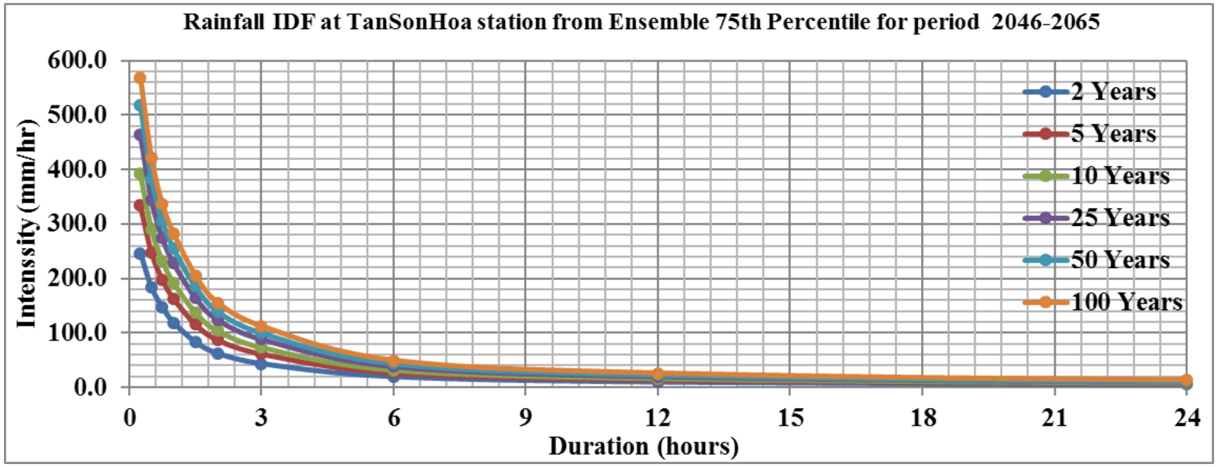
- Increasing in all durations and return periods.
- Comparison with the middle of century: Greater increase in most of duarions and return periods.

Change of rainfall IDF (%)

	15'	30'	45'	60'	90'	2h	3h	6h	12h	24h
2 years	15.4	19.2	23.5	30.5	31.0	30.7	29.6	43.6	43.6	47.2
5 years	26.1	28.2	32.0	37.9	38.1	37.6	35.5	50.0	49.1	57.1
10 years	33.7	32.3	36.0	41.5	41.5	40.0	37.8	52.4	53.1	58.2
25 years	43.6	41.0	46.2	52.1	50.3	48.0	43.5	54.4	55.2	64.1
50 years	49.5	46.0	52.7	58.3	57.0	54.2	49.4	55.8	57.2	66.0
100 years	54.6	50.1	57.7	63.9	62.0	59.6	53.8	56.8	57.8	69.0

3. RESULTS AND DISCUSSION

Higher impact case , in the middle of century (2046-2065)



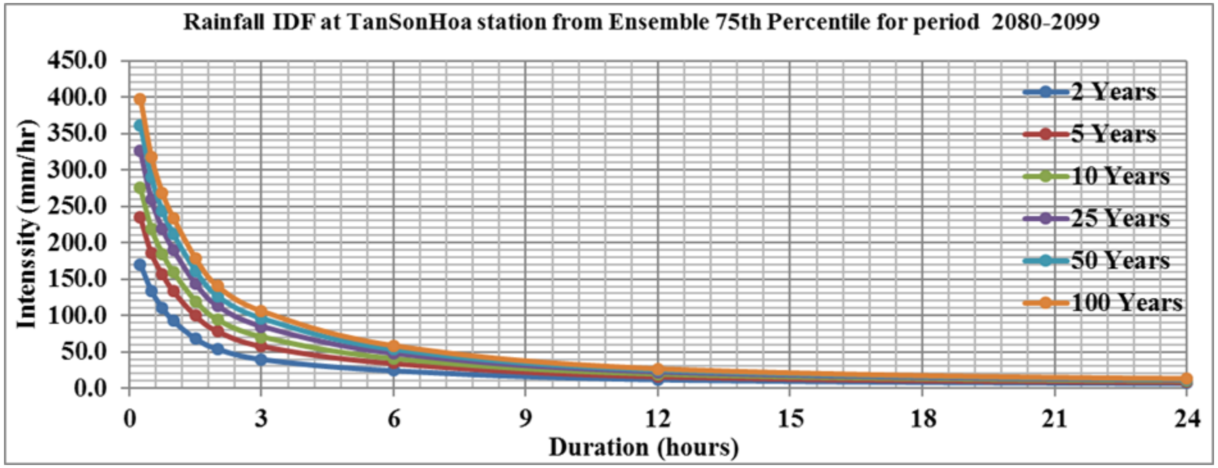
- Increasing in all durations and return periods.
- The change for the middle of century are mostly in the range of 38% and 141%.

Change of rainfall IDF (%)

	15'	30'	45'	60'	90'	2h	3h	6h	12h	24h
2 years	90.2	75.5	70.2	73.3	66.3	61.2	54.0	40.4	41.8	38.5
5 years	112.0	94.0	91.5	95.3	87.6	80.9	71.1	47.7	52.7	53.6
10 years	121.9	102.7	102.3	105.7	97.4	90.7	79.5	55.8	62.4	60.9
25 years	131.3	111.3	112.5	115.5	107.1	99.7	87.2	63.8	71.9	74.2
50 years	137.3	116.0	118.6	121.8	113.3	104.9	92.1	68.9	77.5	79.0
100 years	141.6	119.8	123.0	127.0	117.7	109.4	96.8	72.8	81.6	85.9

3. RESULTS AND DISCUSSION

Higher impact case, in the end of century (2080-2099)



- Comparison with the middle of century: Lower increase in shorter duarions and greater increase in longer durations.
- The changes for the end of century are mainly ranging from 28% to 105%.

Change of rainfall IDF (%)

	15'	30'	45'	60'	90'	2h	3h	6h	12h	24h
2 years	31.7	27.9	28.0	34.4	36.7	38.8	40.6	71.5	71.1	68.2
5 years	48.9	45.1	51.5	59.5	61.8	62.8	61.7	91.3	81.1	78.1
10 years	55.8	53.0	61.0	70.1	72.0	72.1	71.5	96.4	85.5	77.4
25 years	62.6	59.4	69.4	79.0	80.6	81.1	79.1	101.3	86.8	81.9
50 years	65.9	63.3	73.9	83.4	85.9	85.1	83.8	103.9	89.0	82.3
100 years	68.9	65.9	77.9	87.7	89.8	89.2	86.3	105.7	88.4	84.9

4. CONCLUSION

- The results suggest that intensities of rainfall extreme events versus various durations with different return periods are all likely to increase over time in comparison with baseline period: [11, 60]% in 2050s, and [15, 69]% in 2090s under most likely case; and [38, 141]% in 2050s, and [28, 105]% in 2090s under high impact case.
- Such a consistent increase, implying that intense rainfall events are likely to occur more frequently in the future under climate change.
- This results are important for the design and construction of different hydrological structures in water management in Ho Chi Minh City

THANK YOU FOR YOUR ATTENTION!