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# EXPLORING BIAS CORRECTIONS OF RIVER DISCHARGE UNDER DAM OPERATION USING d4PDF IN THE CHAO PHRAYA RIVER BASIN, THAILAND

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# Contents

# Introduction

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|---|---|
| 2011 Great Flood caused by continuous rainstorms at end of July with 143% high rainfall. | Typical monsoon climate prone to natural disasters. |
| Bangkok is low altitude city situated in alluvial plain with 2m elevation. | Large groundwater extraction leading to decline of urban land surface each year increasing the flood risk. |
| ~ 2 million people were affected with fatality of 400 people. | ~ USD 46.5 billion of economic damage and loss ravaged Thailand. |
| 50 and 32 of Thailand's 76 prefectures were affected in 2011 and 2021 flood, respectively. | Climate change influencing the sea level rise in the Gulf of Thailand. |

## 2011 Flood, Thailand

Credit: 2011 Thailand Floods Event Recap Report

Credit: Thailand HAST

## 2021 Flood, Thailand

Credit: Amarin TV

Credit: Amarin TV

# Research Objective

**The main objective of the study is to assess the impact of climate change on future floods by analyzing the combined effect of bias correction at the upstream major dams (Bhumibol and Sirikit) and the downstream outlet of the basin (Nakhon Sawan) in the Chao Phraya River Basin (CPRB).**

- To simulate the river routing model to analyse the bias corrected discharge at the outlet of CPRB;
- To evaluate the combined effect of bias correction at the Bhumibol and Sirikit followed by the downstream outlet of the basin Nakhon Sawan (C2) on simulated discharge;
- To compare the two spatial bias correction methods and select the suitable for future projection of floods in the basin.

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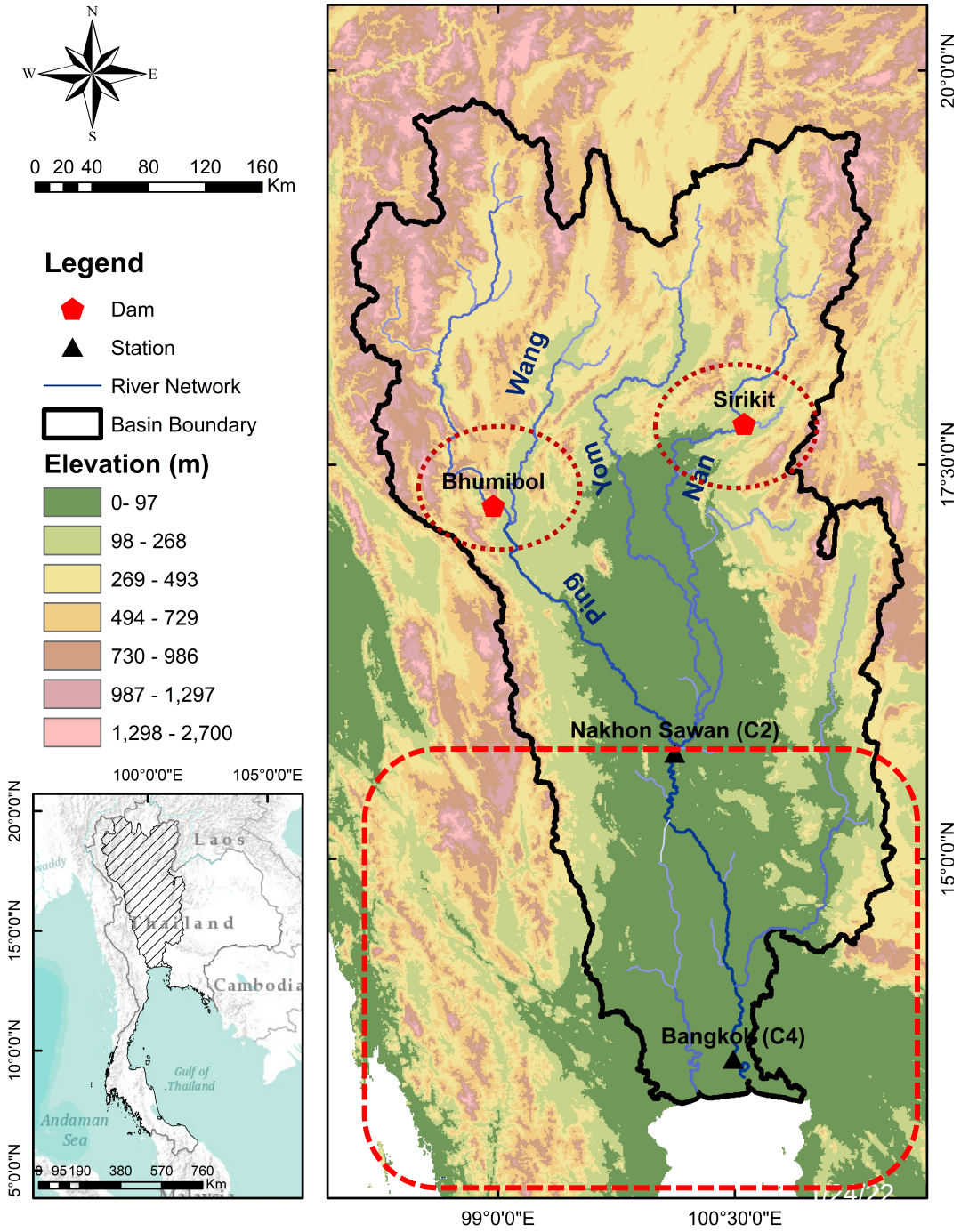
# Study Area

## Chao Phraya River Basin [CPRB], Thailand [99°000 E–101°300 E, 13°150N–17°000N ]

- Originates from the Shan plateau in the northwest of Thailand, flows to the flat area in the south, forms the Chao Phraya River Delta, and finally flows into the Bangkok.
- Catchment Area ~ 1,70,000 $km^2$
- Tributaries - Yom, Nan, Ping, Wang
- **Dry Season – Jan to May**
- **Wet Season – June to December**
- Dry Season ~ 150 $m^3/s$; Rainy Season ~ 2000 $m^3/s$; 90% rainfall from May to October; width ~800 m
- Lower reach ~ 50,000 $km^2$ with crisscross river branches
- Hot and humid climate with abundance of rainfall.
- Densely populated and economically developed area.



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# Observed data

| Station ID | Station Name | Type | Location | Frequency | Duration | Source |
|---|---|---|---|---|---|---|
| BB | Bhumibol | Dam Inflow | Ping | Daily | 1965-2013 | Supattana et al., 2015 |
| SK | Sirikit | Dam Inflow | Nan | Daily | 1974-2013 | Supattana et al., 2015 |
| C2 | Nakhon Sawan | Discharge | Chao Phraya | Daily | 1979-2017 | RID, Thailand |

Topological dataset: Hydrological data and maps based on Shuttle Elevation Derivatives at Multiple Scales (HyDroSHEDS; Lehner, et al. 2006) upscaled to 10 km spatial resolution (Duong et al., 2013)

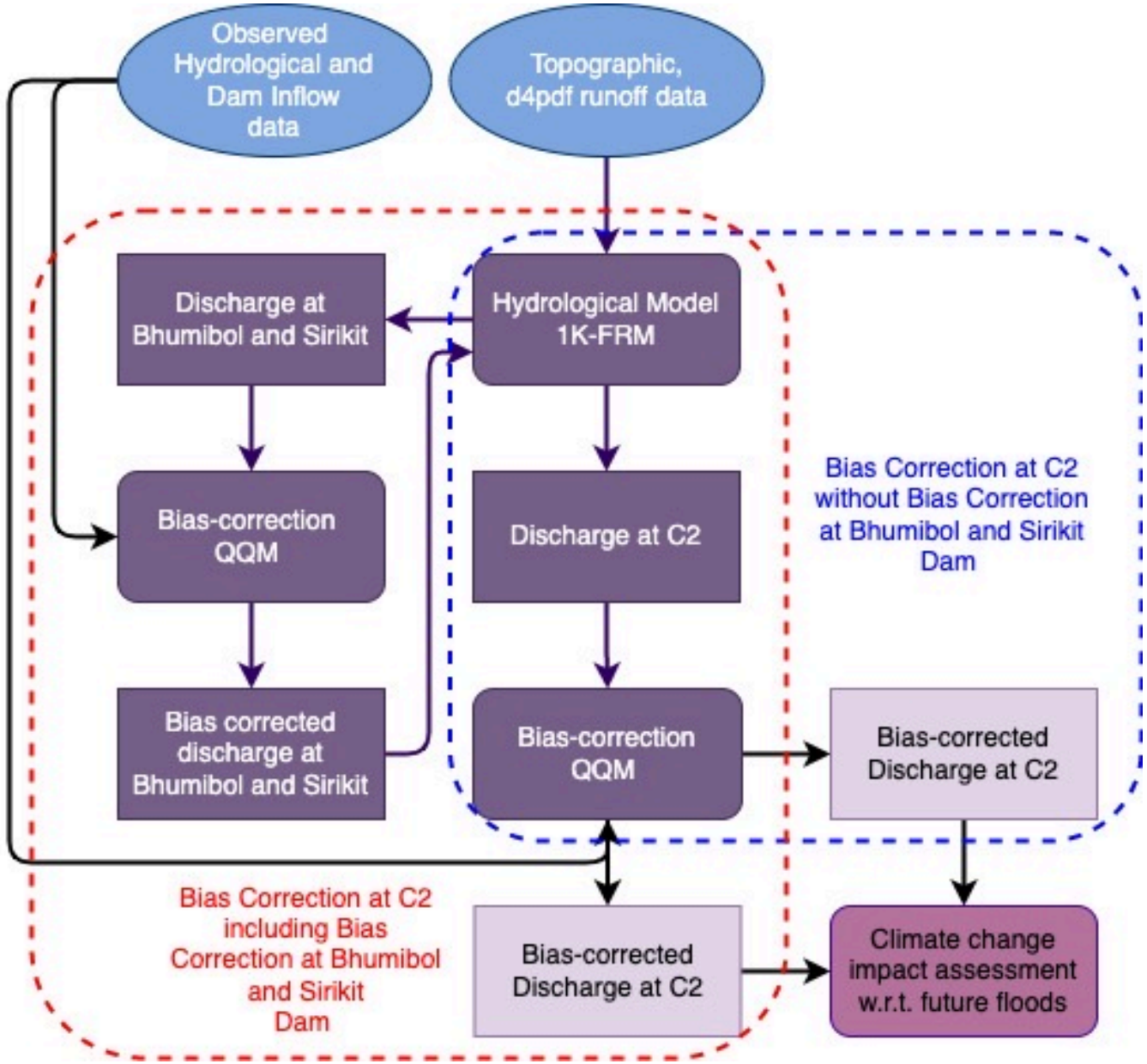
# d4PDF data

Past data (1951 - 2010):100 ensembles
Future data (2051 - 2110): 6 Sea Surface Temperature (SST) models with 15 ensembles each
Resolution of GCM: 60 km

| SST Model | Driving GCM | Institute | Country |
|---|---|---|---|
| CC | CCSM4 | National Centre for Atmospheric Research, | USA |
| GF | GFDL CM3 | Geophysical Fluid Dynamics Laboratory | USA |
| HA | HadGEM2-AO | National Institute of Meteorological Research | Korea |
| MI | MIROC5 | Univ. Tokyo and Japan Agency for Marine-Earth Science and Technology (JAMTEC) | Japan |
| MP | MPI-ESM-MR | Max Planck Institute for Meteorology | Germany |
| MR | MRI-CGCM3 | Meteorological Research Institute | Japan |

# Methodological Framework

- Bias Correction Method : **Quantile-Quantile Mapping(QQM)** for the **discharge**
- TWO STEP - Bias Correction at C2 including Bias Correction at Bhumibol and Sirikit Dam.
- SINGLE STEP - Bias Correction at C2 without Bias Correction at Bhumibol and Sirikit Dam.

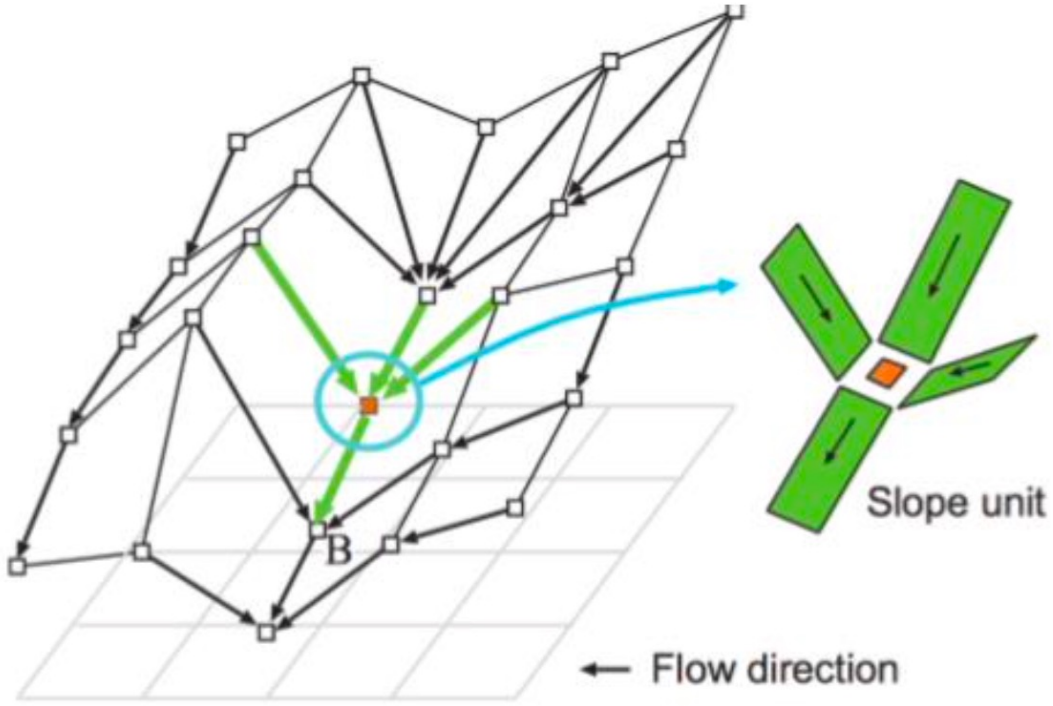


# 1k-FRM Model

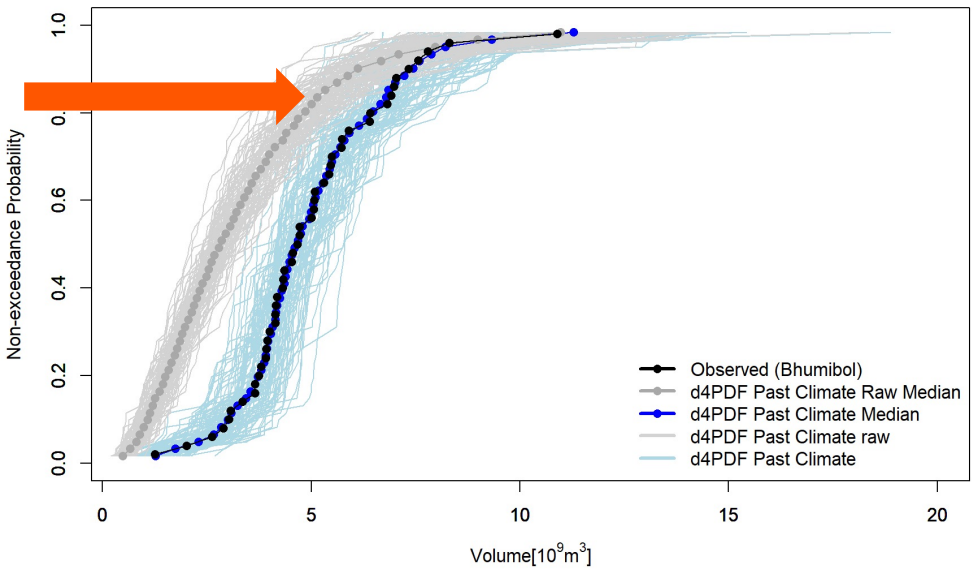
- Physically-based, distributed kinematic-wave flow routing model.
- Developed Hydrology and Water Resource Research Laboratory of Kyoto University.
- The main components of the model are catchment model, flow model, and topographic model.
- Runoff generated by land surface model (SiBUC), embedded in the GCM is converted into a river discharge.
- Rectangular units channel the water downstream based on flow direction.

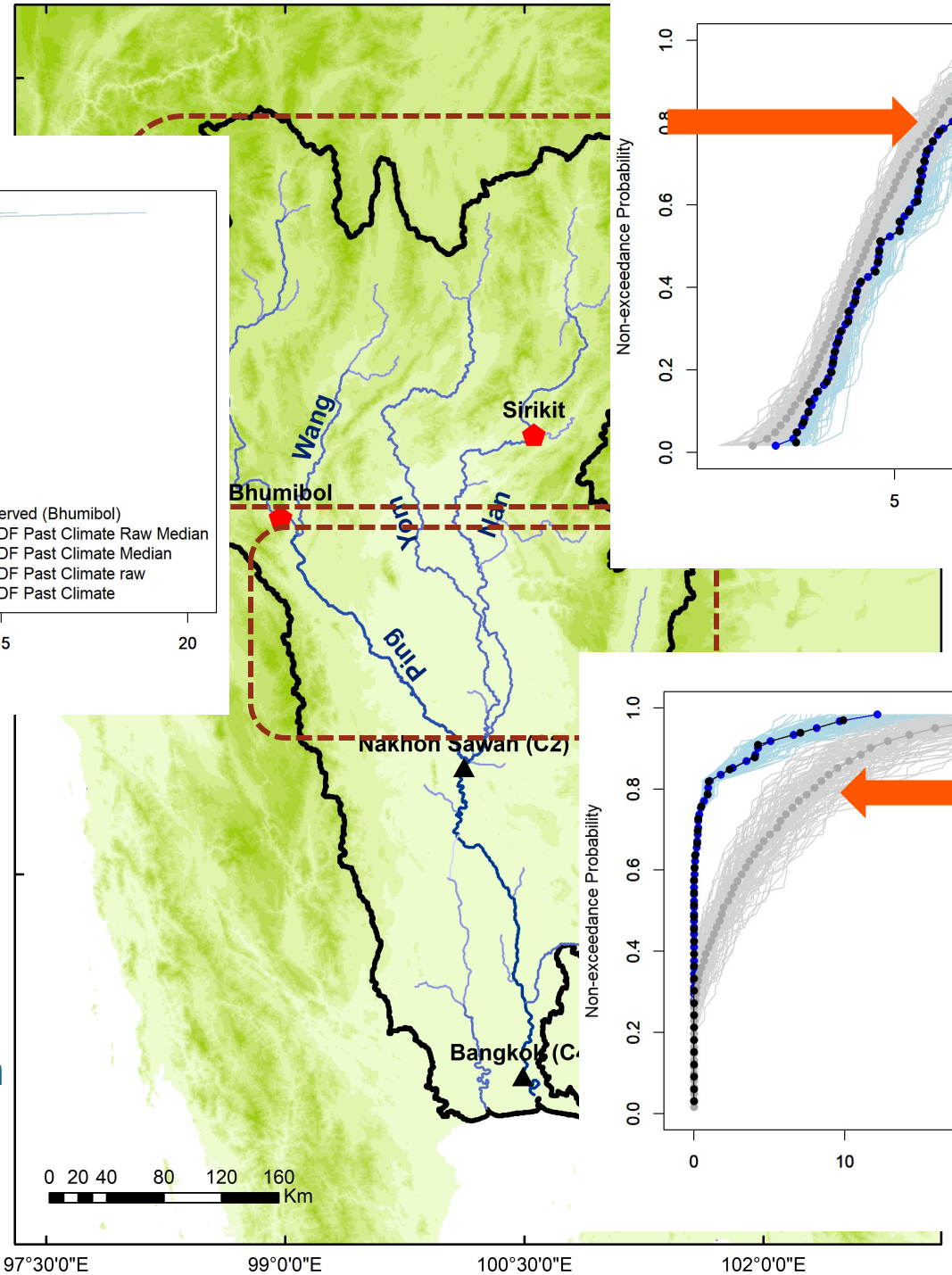
$$\frac{\partial Q}{\partial t} + \frac{\partial A}{\partial x} = q_L(x,t)$$

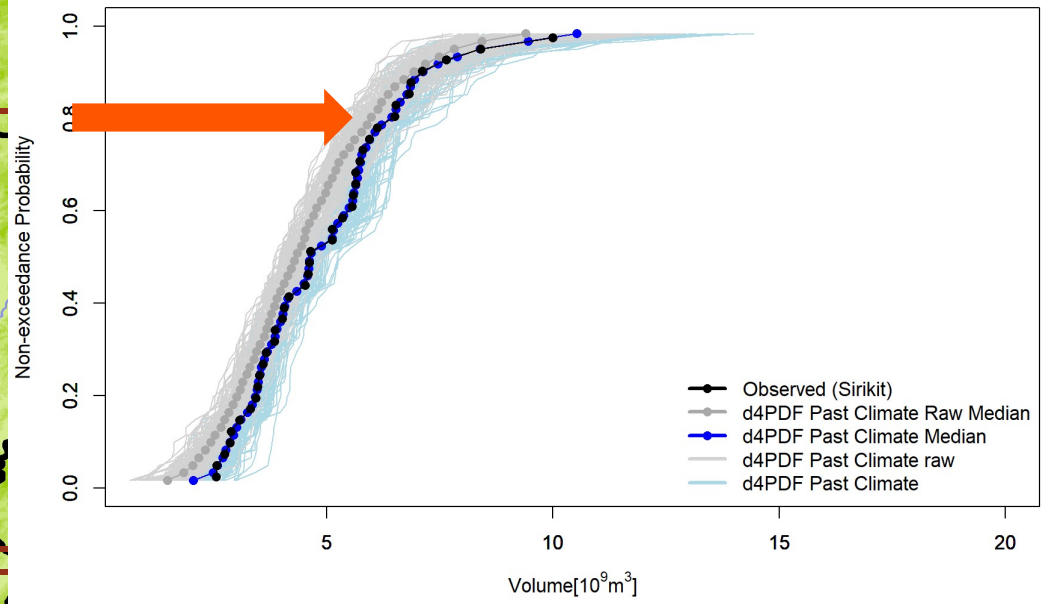
$T$ :time
$x$ : distance from the top of the rectangular grid (unit: m)
$A$ : cross section area on the regular grid (unit: m2)
$Q$ : discharge (unit: m3/s)
$qL(x,t)$ : the lateral inflow per unit length of channel unit given as runoff generated by the MRI-AGCM 3.2H. (unit: m3/s)

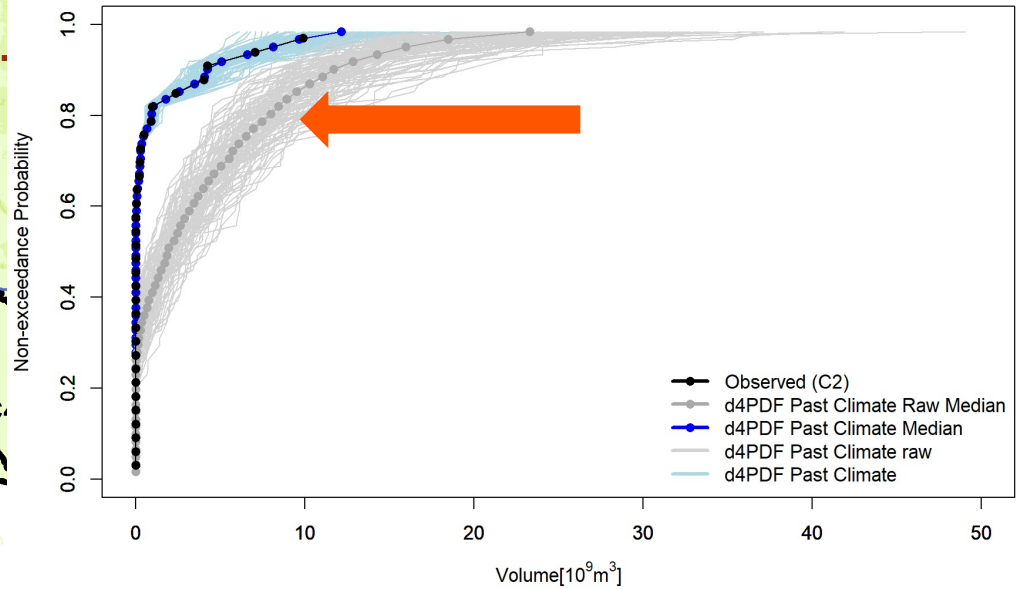


# Result



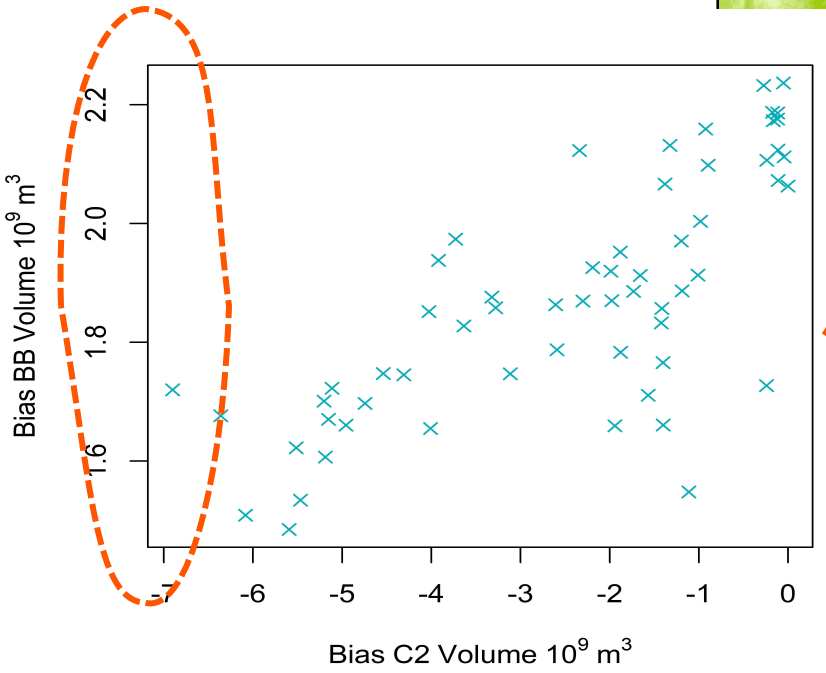



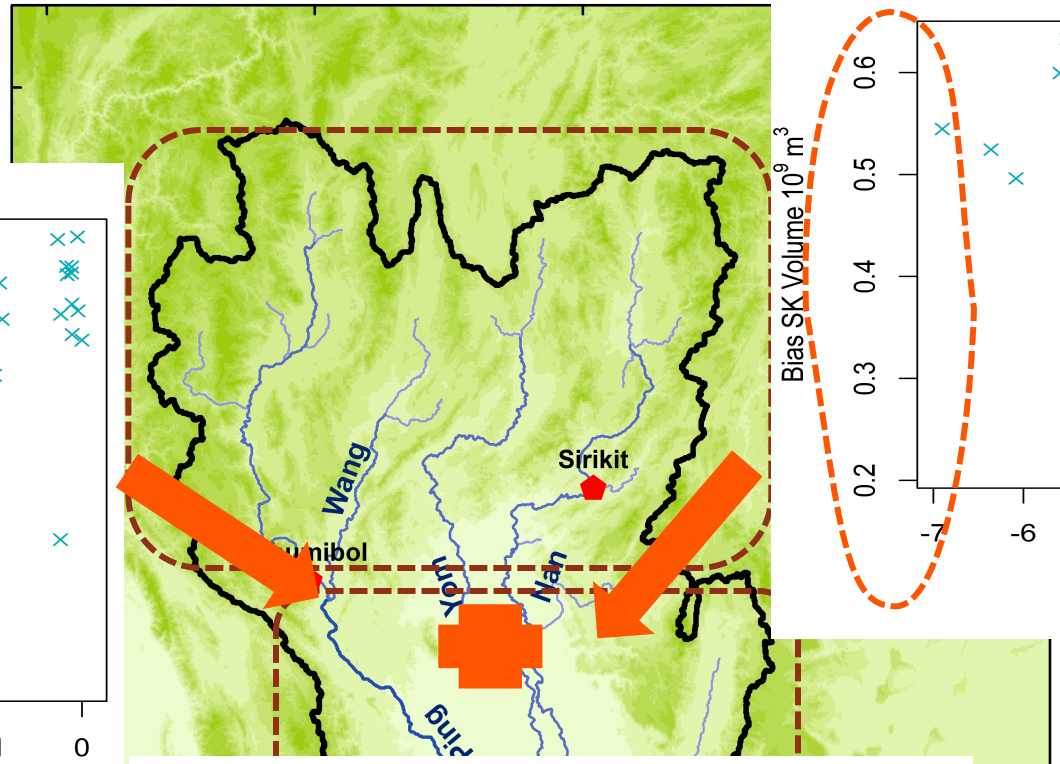



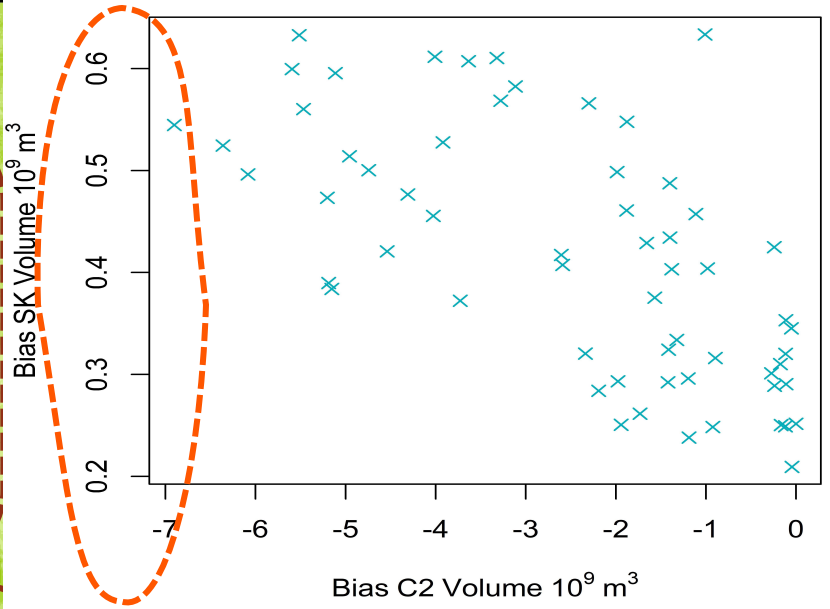



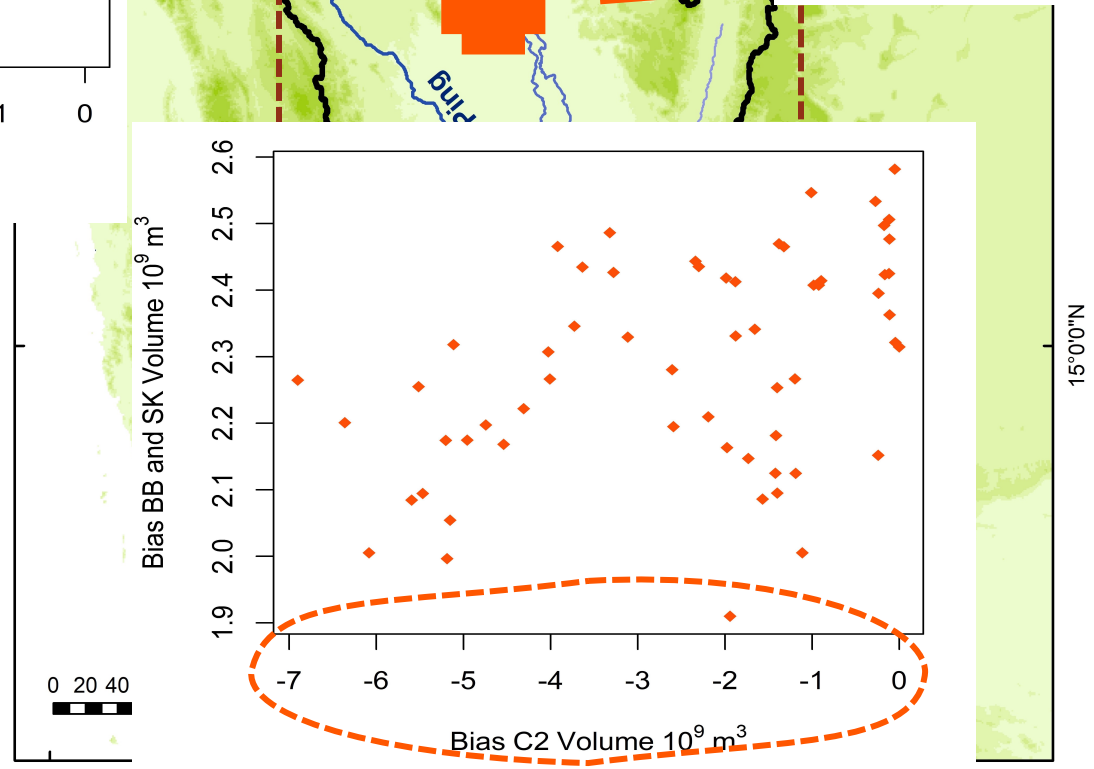

- Past climate raw data are **under-estimated** in comparison to the observed climate simulation for the dams.
- Past climate raw data are **over-estimated** in comparison to the observed climate simulation at C2 station.

# Result



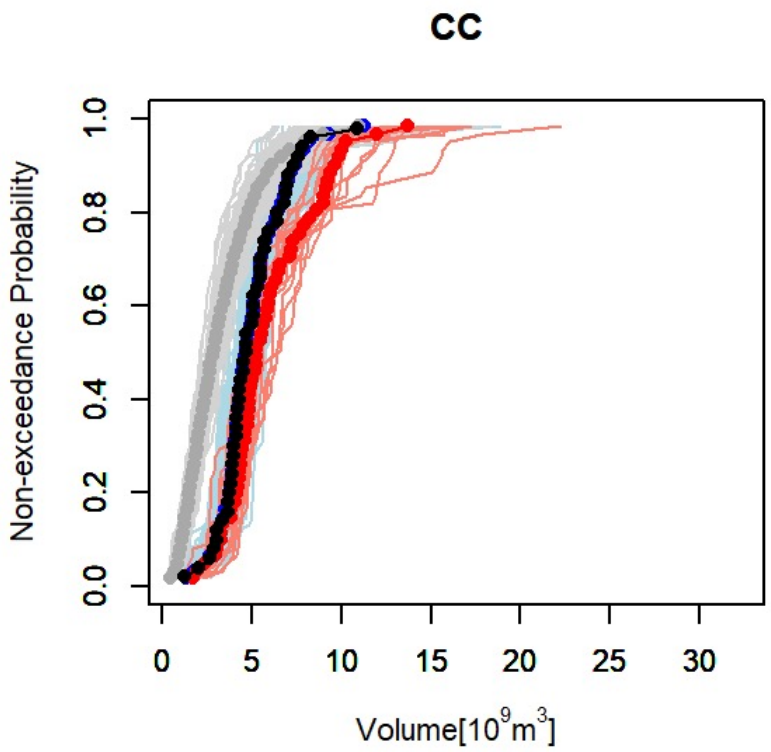



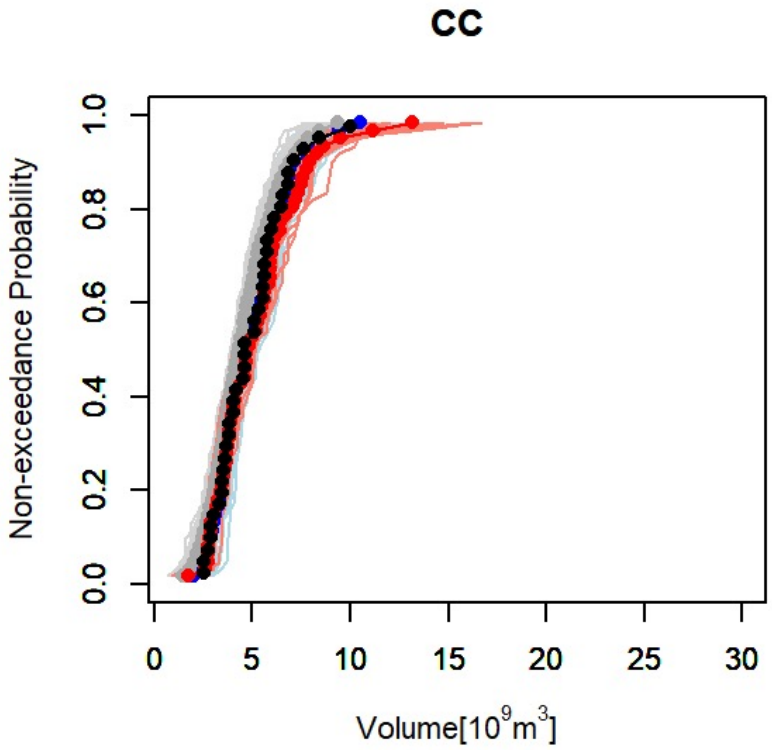

- A large biasness at C2 station which minimizes the effect of upstream Bhumibol and Sirikit dam bias correction.

# Result

Bhumibol Dam (Wet Season)




Sirikit Dam (Wet Season)

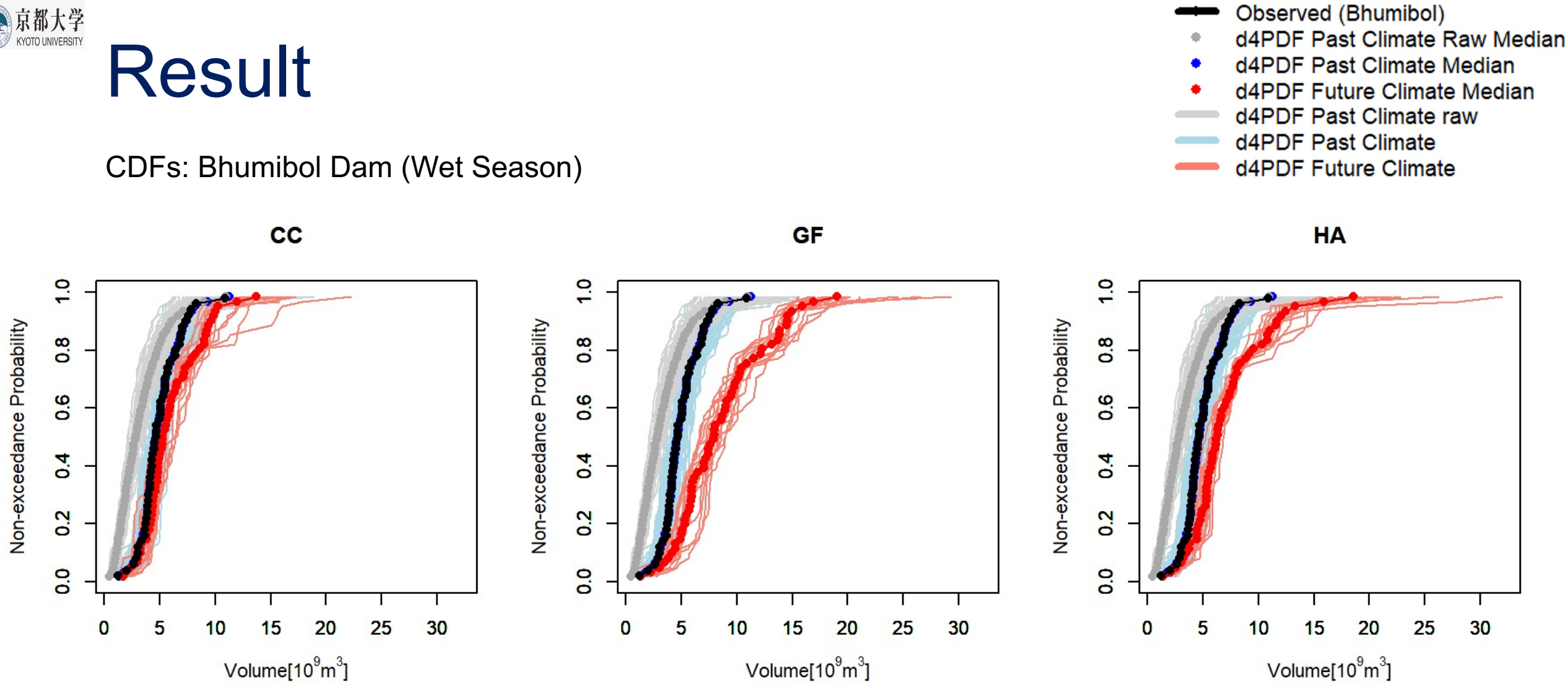




- Increasing trend of future volume members w.r.t. past climate in wet season of Bhumibol dam.
- Similar or slight increase of future volume members w.r.t. past climate in wet season of Sirikit dam.
- Intensity is also stronger and longer for Bhumibol than Sirikit Dam

# Result

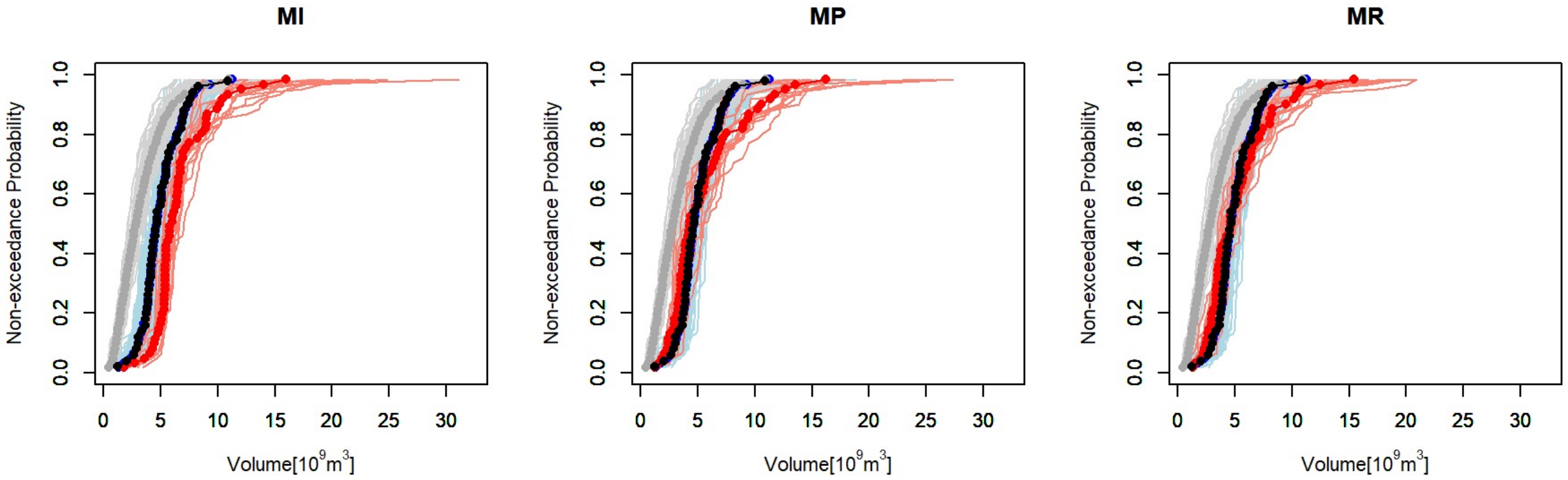
CDFs: Bhumibol Dam (Wet Season)




- Increasing trend of future volume for all SST members w.r.t. past climate in wet season.
- Intensity is also stronger and longer.
- Upper tail of the CDF shows high volume than the past climate for higher return period

# Result

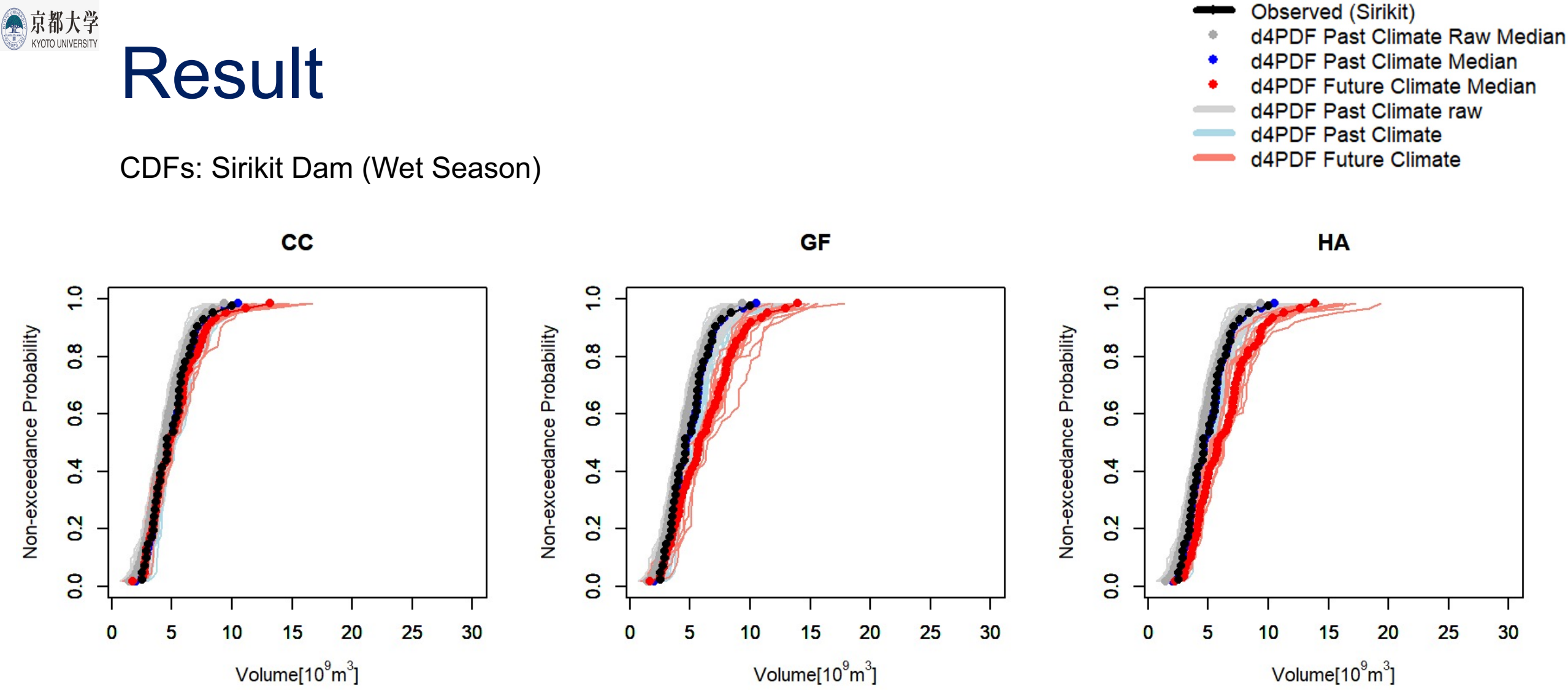
CDFs: Bhumibol Dam (Wet Season)




- Increasing trend of future volume for all SST members w.r.t. past climate in wet season.
- Intensity is also stronger and longer.
- Upper tail of the CDF shows high volume than the past climate for higher return period

# Result

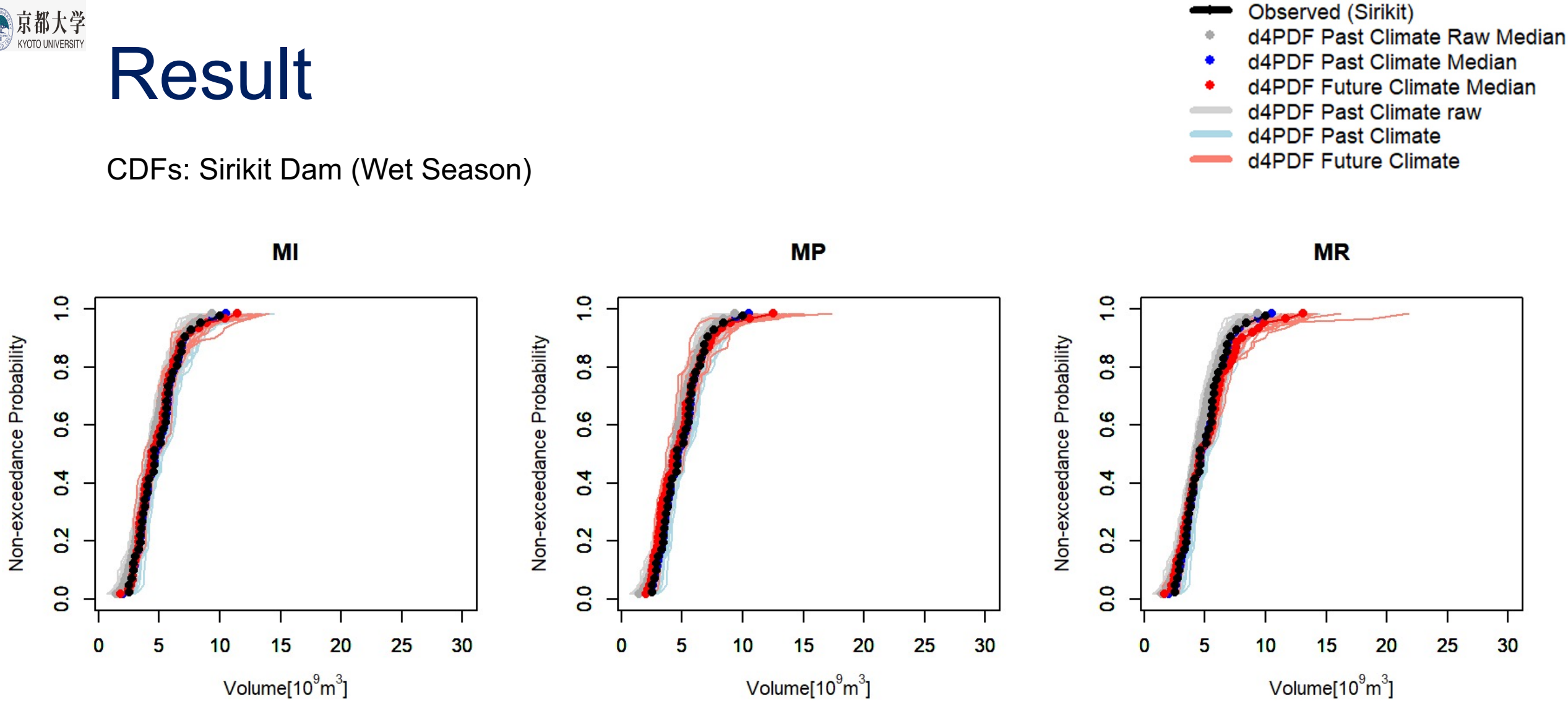
CDFs: Sirikit Dam (Wet Season)




- Similar or slight increasing trend of future volume for all SST members w.r.t. past climate in wet season.
- Intensity is also stronger and longer in some SST (GF, HA, MP, MR)

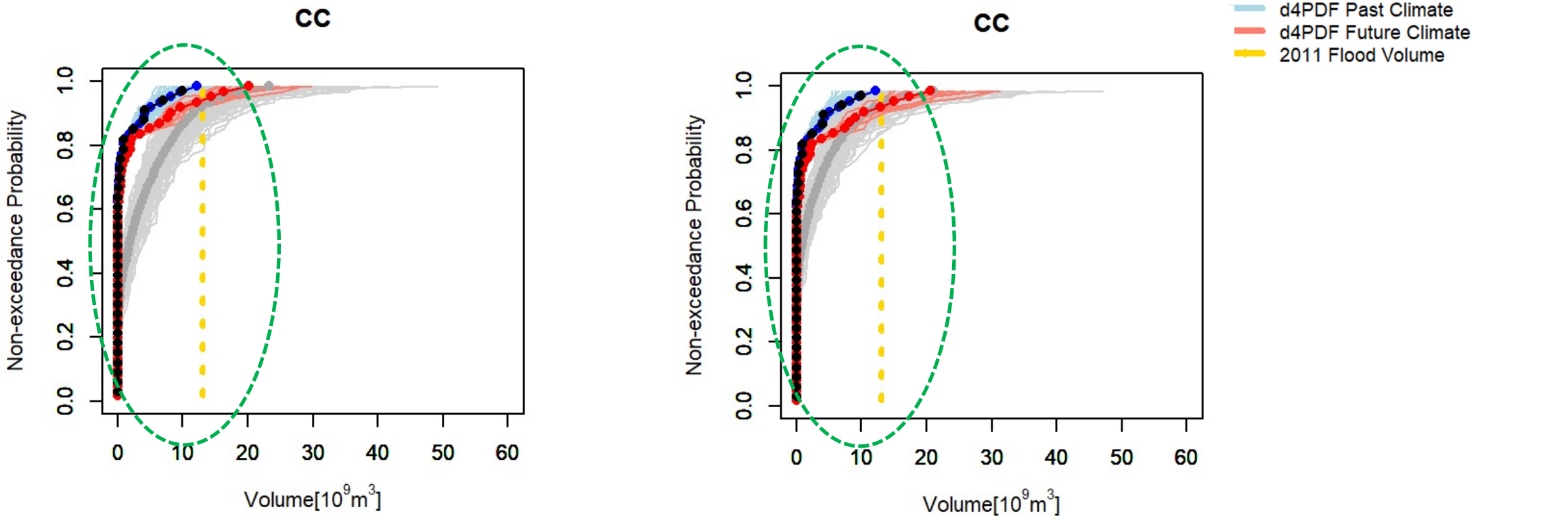
# Result

CDFs: Sirikit Dam (Wet Season)




- Slight increasing trend of future volume for all SST members w.r.t. past climate in wet season.
- Intensity is also stronger and longer.

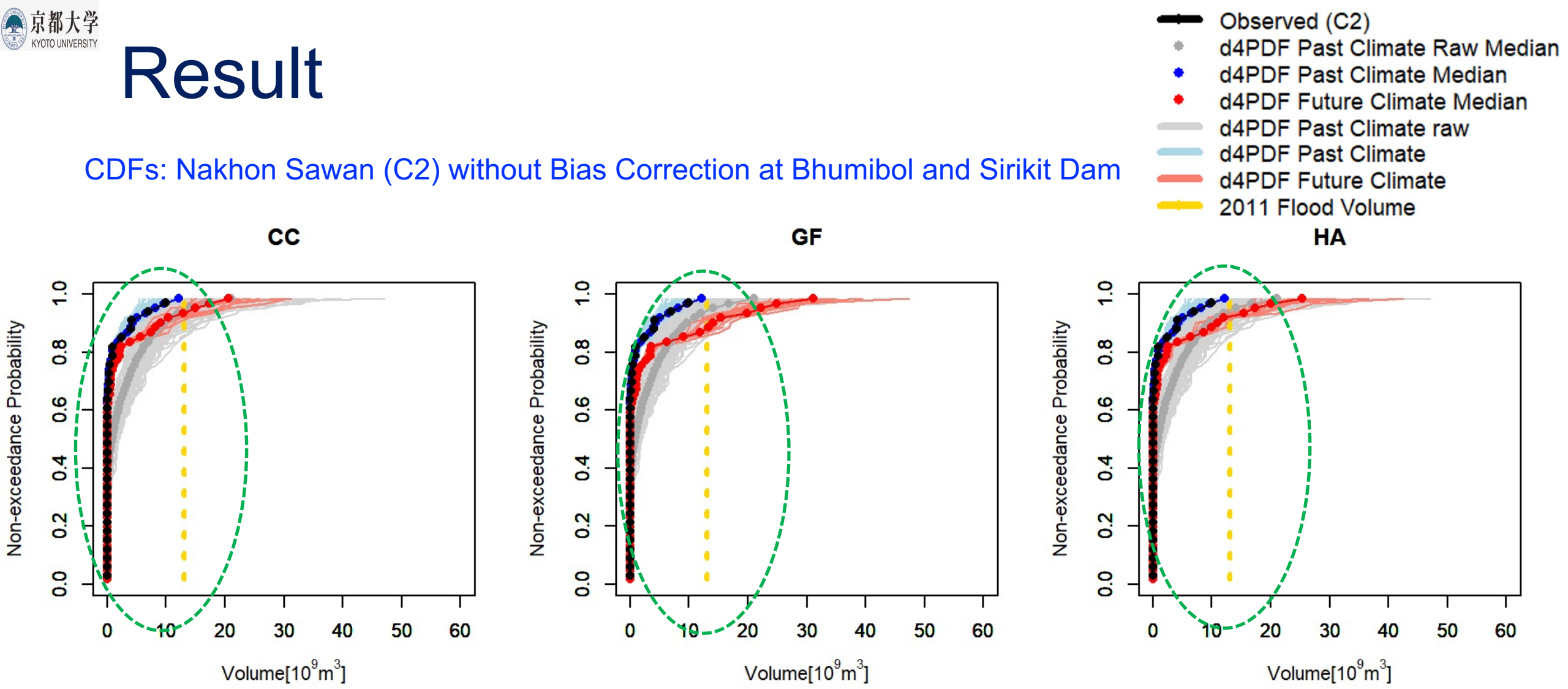
# Result




- **Increasing trend** of future volume for all SST members w.r.t. past climate for Single Step and Two Step.
- Intensity is much stronger and longer for future than past in both cases.
- Future volume are expected to be much higher than the 2011 Thailand Flooding.
- **Not much difference** between Single Step and Two Step spatial Bias Correction

# Result

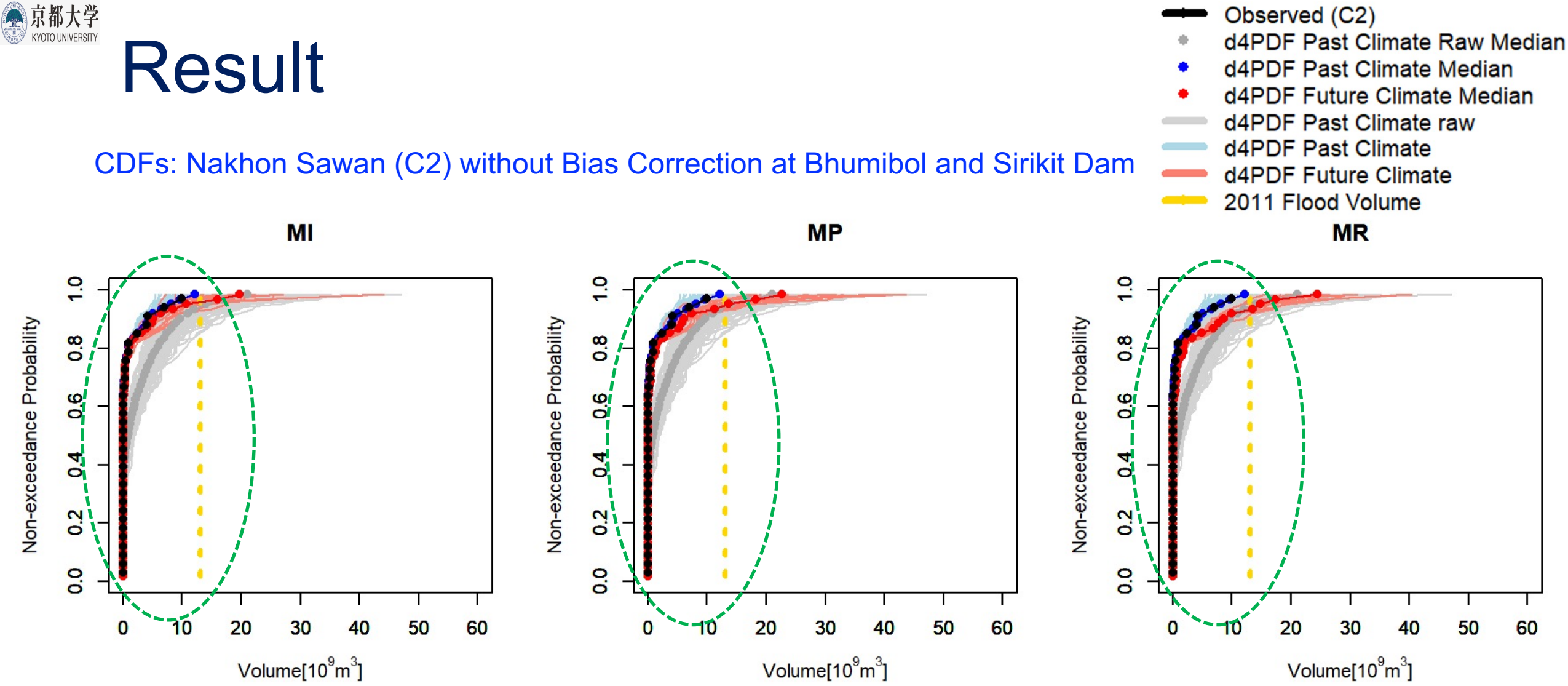
CDFs: Nakhon Sawan (C2) without Bias Correction at Bhumibol and Sirikit Dam




- Increasing trend of future volume for all SST members w.r.t. past climate.
- Intensity is much stronger and longer for future than past.
- Future volume are expected to be much higher than the 2011 Thailand Flooding

# Result

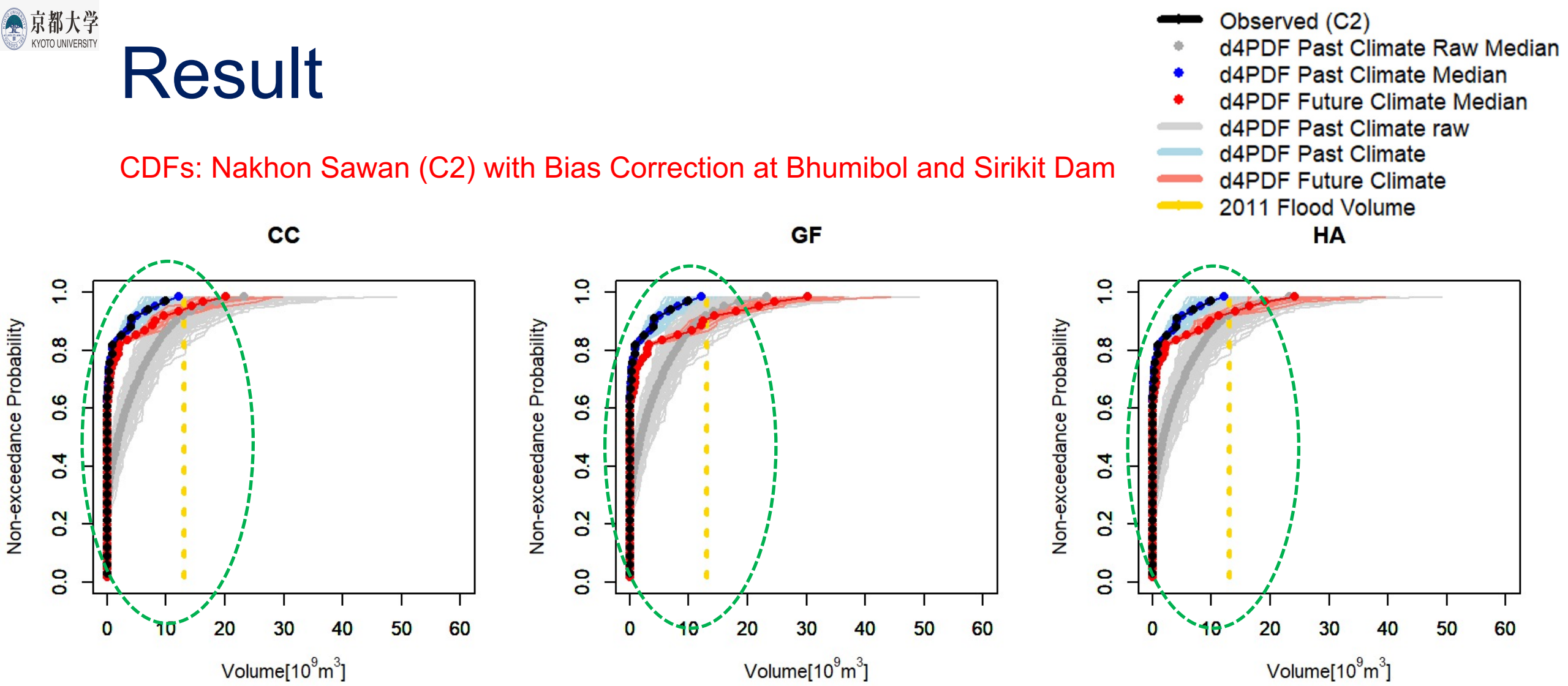
CDFs: Nakhon Sawan (C2) without Bias Correction at Bhumibol and Sirikit Dam




- Increasing trend of future volume for all SST members w.r.t. past climate.
- Intensity is much stronger and longer for future than past.
- Future volume are expected to be much higher than the 2011 Thailand Flooding

# Result

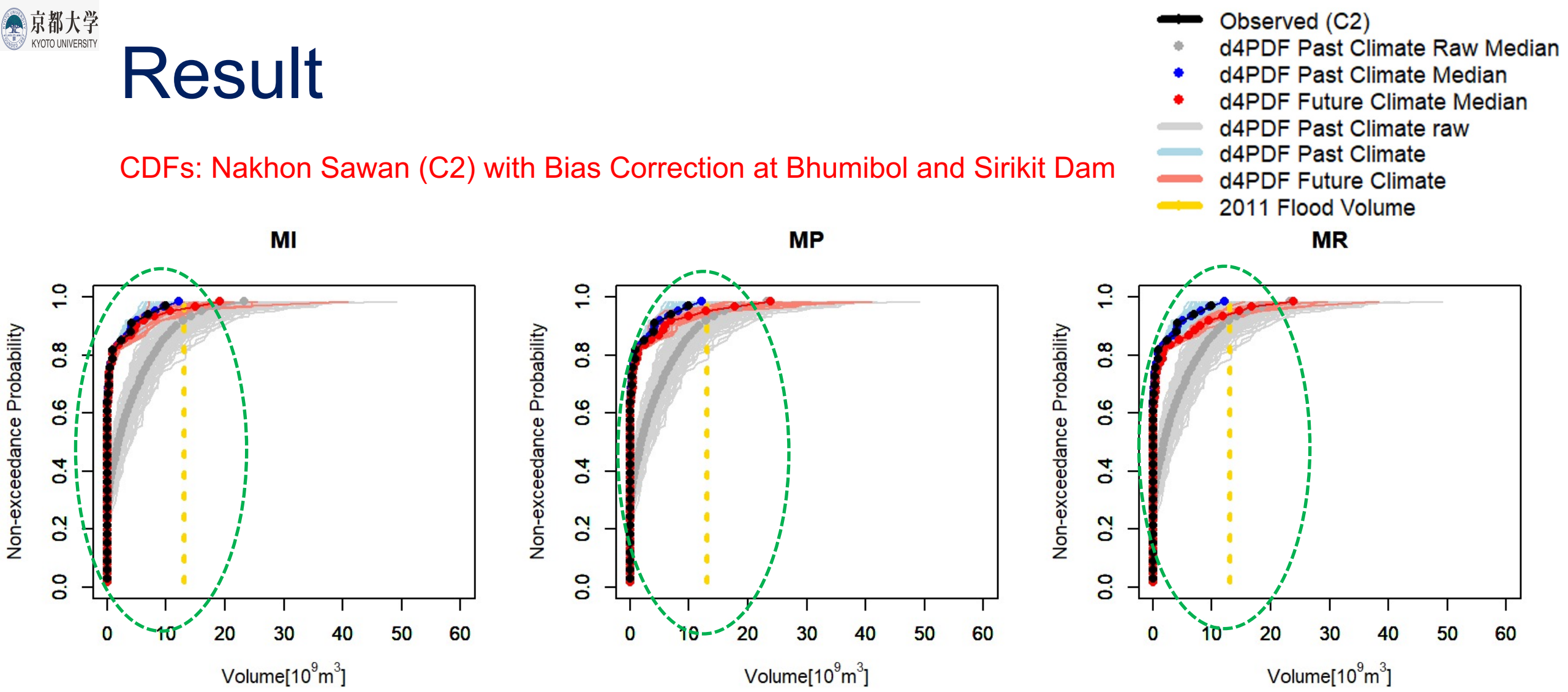
CDFs: Nakhon Sawan (C2) with Bias Correction at Bhumibol and Sirikit Dam




- Increasing trend of future volume for all SST members w.r.t. past climate.
- Intensity is much stronger and longer for future than past.
- Future volume are expected to be much higher than the 2011 Thailand Flooding

# Result

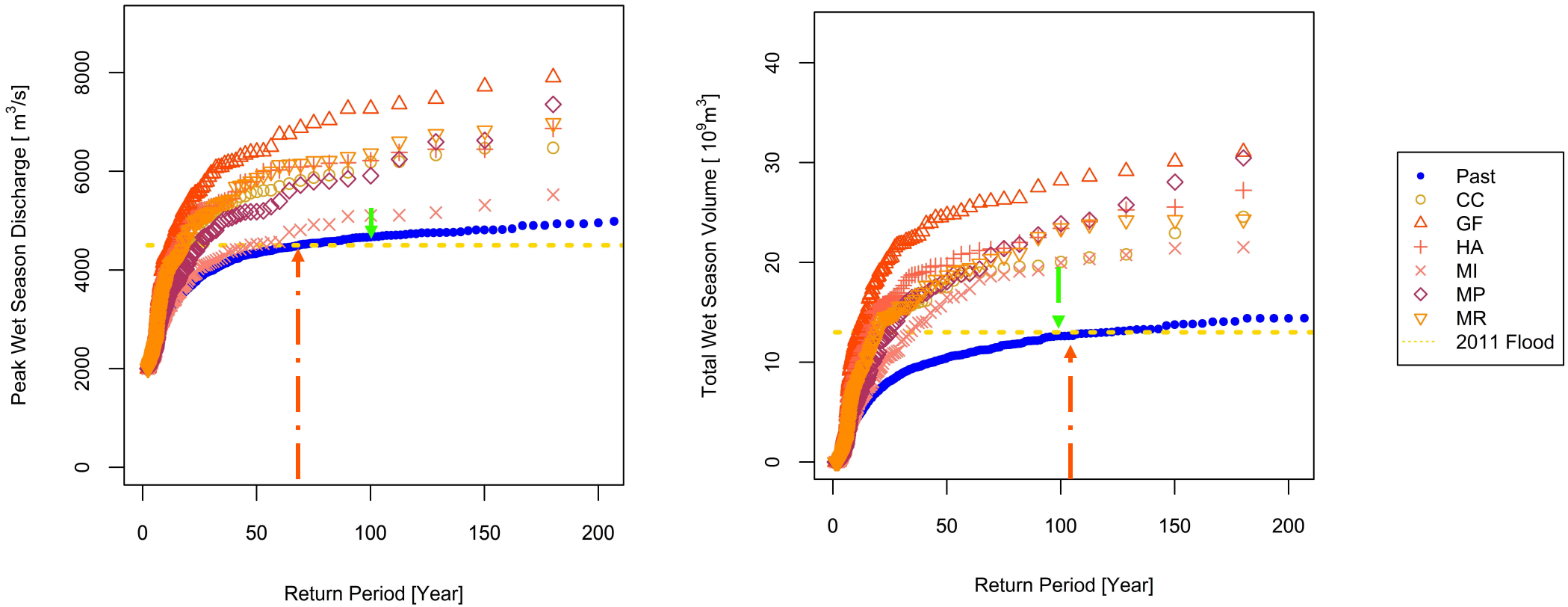
CDFs: Nakhon Sawan (C2) with Bias Correction at Bhumibol and Sirikit Dam




- Increasing trend of future volume for all SST members w.r.t. past climate.
- Intensity is much stronger and longer for future than past.
- Future volume are expected to be much higher than the 2011 Thailand Flooding

# Result

## Return Periods vs peak discharge > 2000m$^3$/s and volume at C2 (TWO STEP)




- ~70 year return period event was corresponding to 2011 Thailand Flood discharge whereas ~100 year return period total volume 2011 Thailand Flood volume
- All GCMs shows increased peak discharge (> 2000 m$^3$/s) and volume in future for the same return period in past. Less return period, higher intensity and more frequent floods than 2011 Thailand flood.
- Future discharge event similar to 2011 Thailand Flood are likely to occur with higher volume having a long term impact

# Result

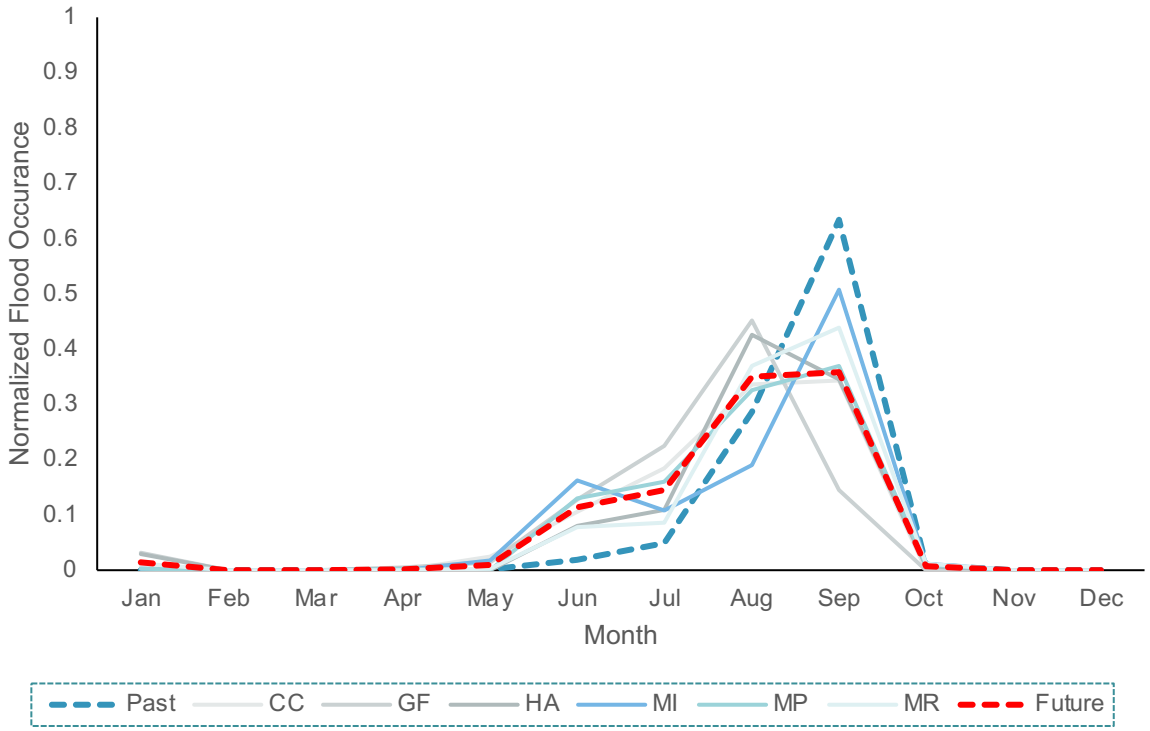
Return Periods of peak wet season discharge (C2) with Bias Correction at Bhumibol and Sirikit Dam

| Two Step | 50y | 100y | 200y | 500y |
|---|---|---|---|---|
| Present | 4336($m^3/s$) | 4668($m^3/s$) | 4955($m^3/s$) | 5257($m^3/s$) |
| CC | 1.3 | 1.3 | 1.3 | 1.5 |
| GF | 1.5 | 1.6 | 1.6 | 1.7 |
| HA | 1.4 | 1.3 | 1.4 | 1.5 |
| MI | 1.1 | 1.1 | 1.1 | 1.2 |
| MP | 1.2 | 1.3 | 1.5 | 1.7 |
| MR | 1.4 | 1.4 | 1.5 | 1.5 |

- All GCMs shows an increase between **1.1 – 1.6 times** the peak discharge for future100 year return period.

# Result

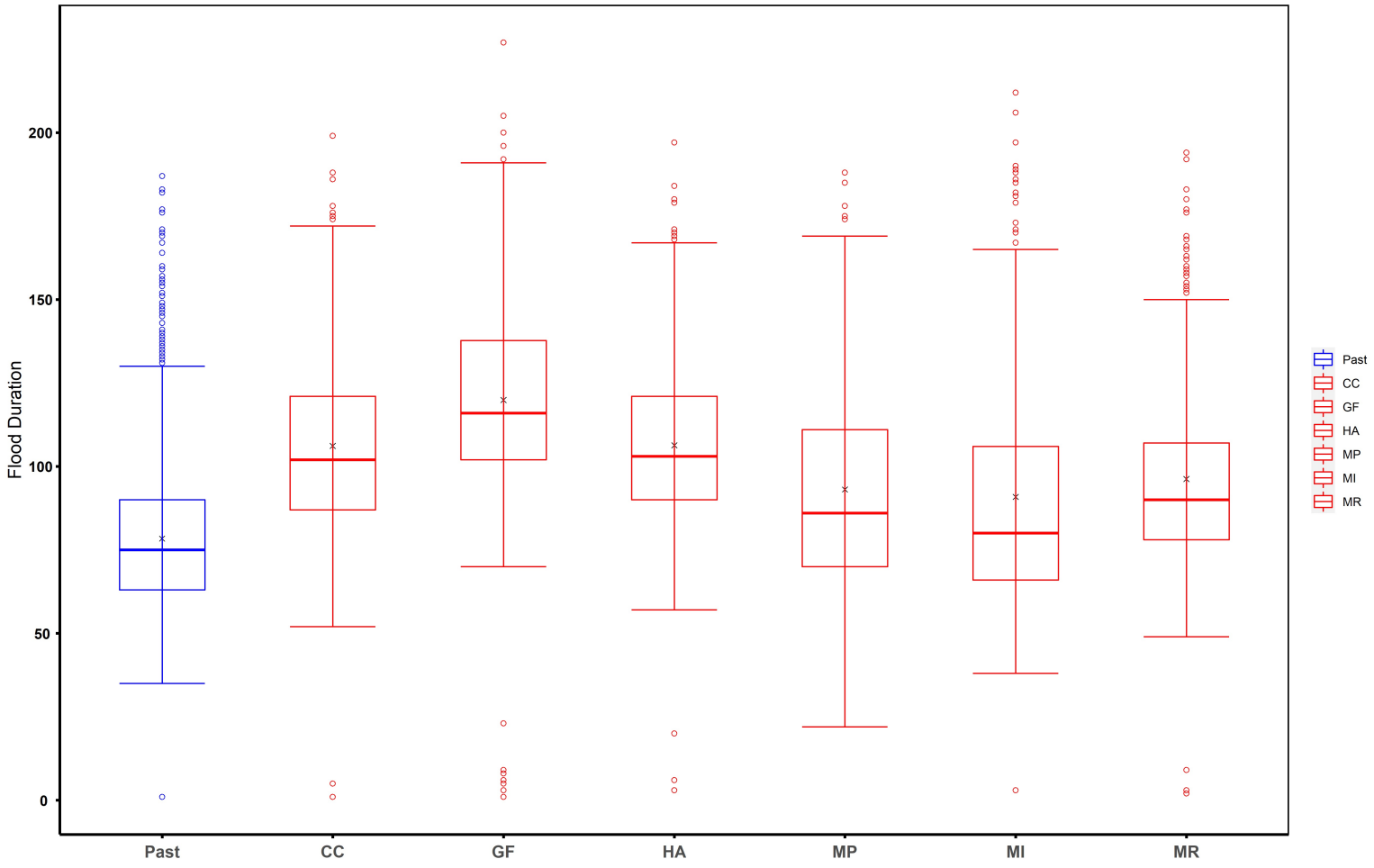
Starting wet season flood month at the outlet of the Chao Phraya  River Basin.




- The no. occurrence of floods during the past is maximum in September.
- No of occurrence for future floods is going to be equally high in August as well as September.
- Additionally, increased occurrences in June July as well.

# Result

Duration of wet season flood at the outlet of the Chao Phraya  River Basin.




- Higher and prolonged duration of floods is likely to occur in all SST ensemble scenarios in comparison to past.
- In average during the past, 60-90 days the flood (>2000 m3/s discharge) used to occur whereas 70-130 days the flood (>2000 m3/s discharge) is likely to occur in future.

# Conclusion

- Raw past climate ensemble results shows **under estimated** discharge at Bhumibol and Sirikit whereas raw past climate ensembles shows **overestimated** discharge at the C2 station in comparison to the observed data.
- There is **not much difference** between bias correction results at C2 with (Two Step) and without (Single Step) bias correction at Bhumibol and Sirikit dam.
- It is due to **large biasness at C2 station** which **minimizes** the effect of **upstream dam bias correction**.
- Therefore, a robust method i.e. Bias correction including dam bias correction (Two Step) is applied for future analysis.
- **Future discharge event similar to 2011 Thailand Flood** are likely to occur with **higher volume** having a long term impact.
- Future floods are likely to increase **1.1 to 1.6 times for 100 return** period.
- The **starting month** of the highest flood occurrence is going to be equally high in **August and September** resulting in a prolonged duration of floods in the future for all SST ensemble scenarios.

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# THANK YOU FOR YOUR ATTENTION!