CHULA ENGINEERING
Foundation toward Innovation
WATER RESOURCES

Overview of Research Projects on Water-related Disaster and Climate Change

Dr. Piyatida Ruangrassamee
Department of Water Resources Engineering
Chulalongkorn University

Outline

- Thailand's Water Security Situation in the context of world and ASEAN
- Research Projects by Water Resource System Research Unit (WRSRU)
- Precipitation Patterns and Extremes in Thailand
- Evaluation of Satellite Rainfall Estimates for Application of Flood Simulation

Water Security

Table 1 The average world, Asia and ASEAN water use status and the ranking of Thailand's

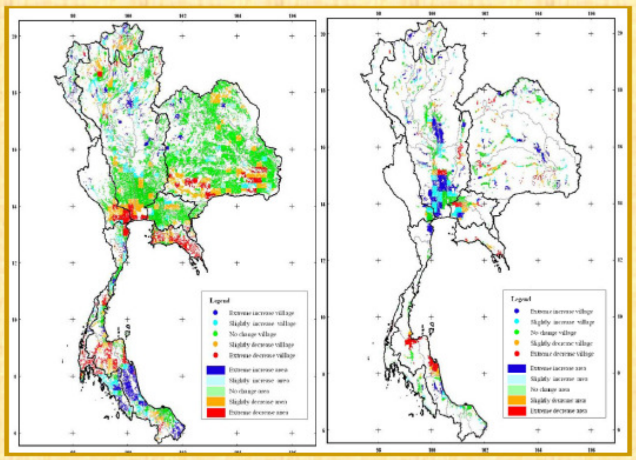
Items	Elements	World average	World ranking	Asia average	Asia ranking	ASEAN average	ASEAN ranking	Thailand
Basic water	1. fresh water renewable (m^3/capita)	22,167	79	10,854	15	19,205	8	6,382
	2. water supply (m^3/capita)	84	46	84	9	85	3	98
	3. sanitation water (m^3/capita)	67	15	70	6	71	2	96
Sufficient water	1. water use per capita (m^3/capita)	511	12	842	9	531	7	1,391
	2. house holds (m^3/capita)	84	46	84	9	85	3	98
	3. agricultural water (m^3/capita)	354	159	712	7	424	1	1,322
Water for development	1.irrigation area (%)	19	49	41	30	18	3	25
	2.industrial water (m^3/capita)	97	68	60	18	49	4	34
	3.water for energy (%)	31	89	20	23	14	6	4
	4. water for fresh water aquaculture (m^3/capita)	346,734	4	1,241,323	4	582,458	2	1,385,801
Water disaster	1.flood damage (US$)	3,543,108	3	8,670,092	2	6,002,888	1	41,051,592
	2.drought damage (US$)	1,261,531	22	1,896,770	5	239,512	2	424,300
Water for future	1.population growth (%)	1.3	137	1.43	38	1.31	10	0.43
	2.urban population growth (%)	63	147	59	30	59	7	42
	3.water footprint (m^3/capita)	1,338	7	1,304	2	1,697	2	2,223
Water productivity	1.GDP (10^6 US$)	343,530	29	445,799	7	151,224	2	318,907
	2.productivity(US$ / m^3 water)	81	132	41.3	132	117.3	6	3.6
	3.agricultural productivity (US$ / m^3 water)	392	124	33.8	18	162.5	7	0.32
	4.industrial productivity(US$ / m^3 water)	169.1	63	69.5	8	121.6	4	51.2

SUCHARIT KOONTANAKULVONG[1], PIAMCHAN DOUNGMANEE[2] & PIYATIDA HOISUNGWAN [1]
1 Faculty of Engineering, Chulalongkorn University, Thailand
2 Research Center, National Institute of Development Administration, Thailand

Research Projects by WRSRU

Technical Report

GCM data comparison and its application to water disaster adaptation measures in Thailand



Assoc.Prof.Dr. Sucharit Koontanakulvong
Mr. Winai Chaowiwat

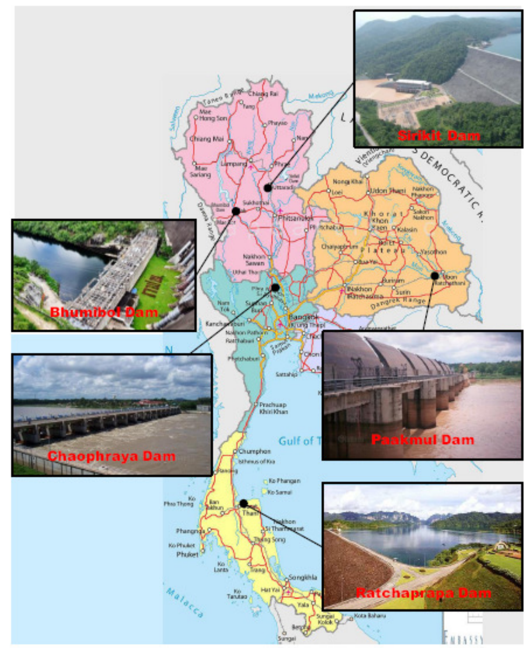
Water Resources System Research Unit
Faculty of Engineering, Chulalongkorn University

March 2011

Final Report

Research Project on

"The Impact of Climate Change on Irrigation Systems and Adaptation Measures (Dam Operation Analysis)"



By
Water Resources System Research Unit
Faculty of Engineering, Chulalongkorn University
February 2013

Precipitation Patterns and Extremes in Thailand: Comparison between MRI-AGCM 3.1S and 3.2S

The Third China – Thailand Joint Seminar on Climate Change

Assoc. Prof. Dr. Sucharit KOONTANAKULVONG

Dr. Piyatida HOISUNGWAN

Patinya HANITTINAN

Department of Water Resources Engineering, Chulalongkorn University

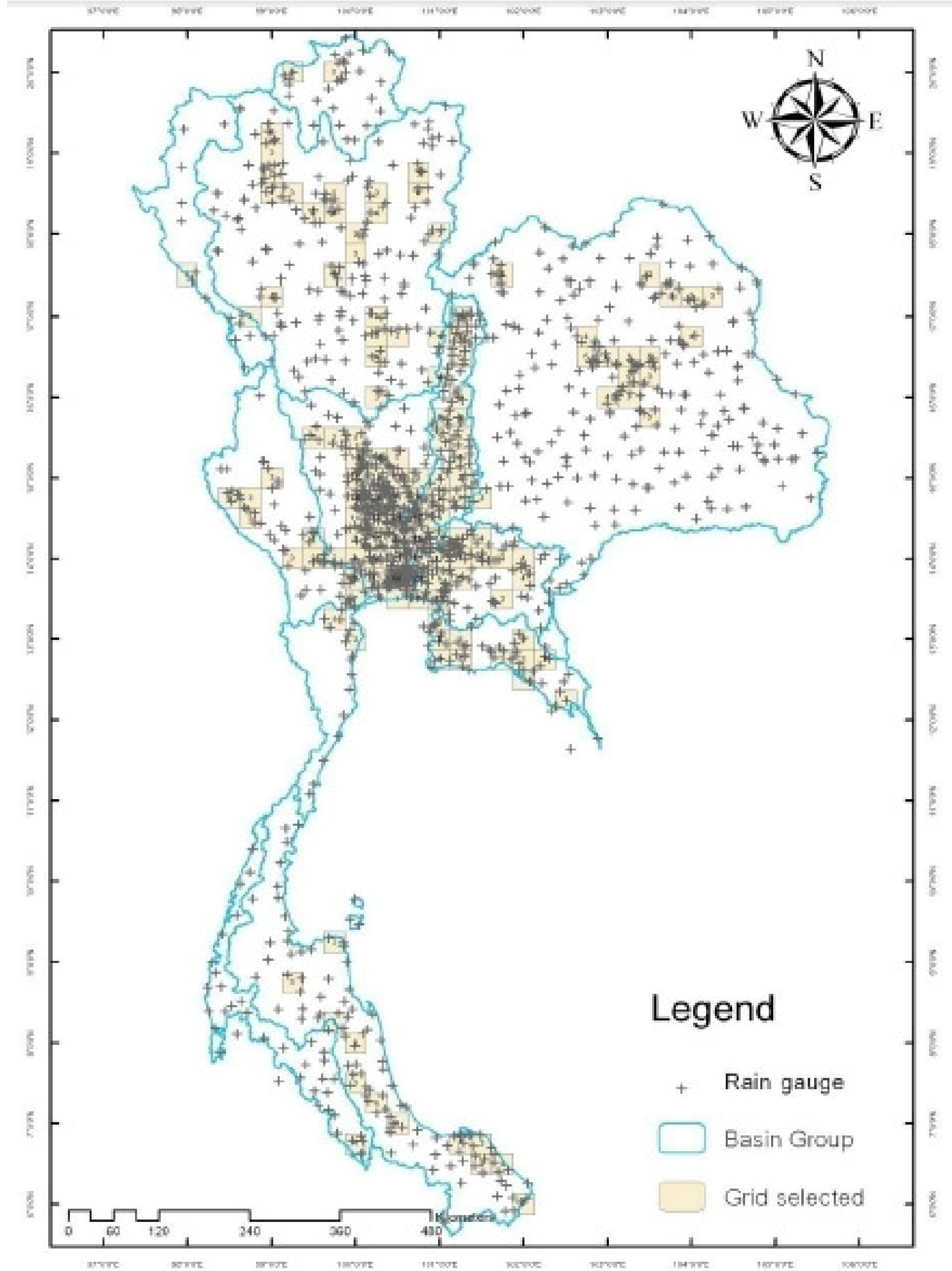
Research Objectives

- Review outputs from AGCMs and correct AGCM precipitation bias with the focus on extreme values
- Study precipitation extremes in river basins in Thailand
- Compare precipitation extreme patterns in the future between AR4 and AR5

Scope of Research

- Study area covers all river basins in Thailand
- Observed rainfall obtained from Thai Meteorological Department (TMD) and Royal Irrigation Department (RID) during the period of 1979-2006
- Use outputs from MRI – AGCM 3.1S (AR4) and MRI – AGCM 3.2S (AR5) with the grid size of 20 x 20 km during the period of 1979-2006 and 2015-2039

Map of rain gauges



Studies on Extreme Precipitation

- Joint World Meteorological Organization (WMO) Commission for Climatology (CCI) / World Climate Research Program (WCRP), Climate Variability and Predictability (CLIVAR) project's Expert Team on Climate Change Detection and Indices (**ETCCDI**)
- **Limjirakan et al (2010)** studied trends in climate change indices in Thailand, with a focus on weather extreme events during 1956-2006.
  - Total rainfall, number of rainy days and frequency of heavy rainfall days showed widespread and general decrease in the central, north and south. Associated changes were noticed by spatially coherent increases in daily intensity rainfall and consecutive dry day

Studies on Extreme Precipitation

- **Xu et al. (2011)** applied observed precipitation data and three GCMs (CSIRO-MK3, MPI-ECHAM5 and NCAR-CCSM 3.0) - with SRES A1B scenarios, to simulate extreme precipitation
  - These GCMs are able to reproduce trends of spatial distribution with degree of high fidelity, compare with observed precipitation. But they are failed to correctly represent inter-annual variation.
  - Analyzed rainfall indices were: Simple Daily Precipitation (SDII) R95T Consecutive Dry Days (CDD) Consecutive Wet Days (CWD) R10
  - All of them have shown increasing trend in every major river basin in China

Statistical Bias Correction Methods

- Gamma – Gamma transformation method: intensity, frequency and mean rainfall correction

- Hybrid quartile method:
  extreme precipitation correction

Bias correction method: Gamma – Gamma transformation

Bias correction method for daily GCM rainfall

Purpose: To reconcile the difference between GCM and local observed data

Rainfall frequency correction

1. Establish the empirical distribution, F(x)

$$F(x) = \frac{n}{m+1}$$

2. Calculate a threshold value (%xGCM), derived from the empirical distribution of daily historical rainfall, to truncate the empirical distribution of the raw daily GCM rainfall for that particular month. Basically, we have to determine F(xhis=0.0) then map it to the daily GCM rainfall distribution

Bias correction method: Gamma – Gamma transformation

Rainfall Intensity correction

1. Gamma – Gamma transformation

$$f(x;\alpha,\beta)=\frac{1}{\beta^{\alpha}\Gamma(\alpha)}x^{\alpha-1}\exp\left(-\frac{x}{\beta}\right)\ ;$$

$$x \geq x_{trunc}$$

$$F(x;\alpha,\beta)=\int_{x_{trunc}}^{x} f(t)dt$$

$$F(x_{GCM};a,\beta|_{GCM}) \Rightarrow F(x_{His};\alpha,\beta|_{His})$$

2. The corrected GCM rainfall amount for that day can be calculated by taking the inverse eq. (4) such that

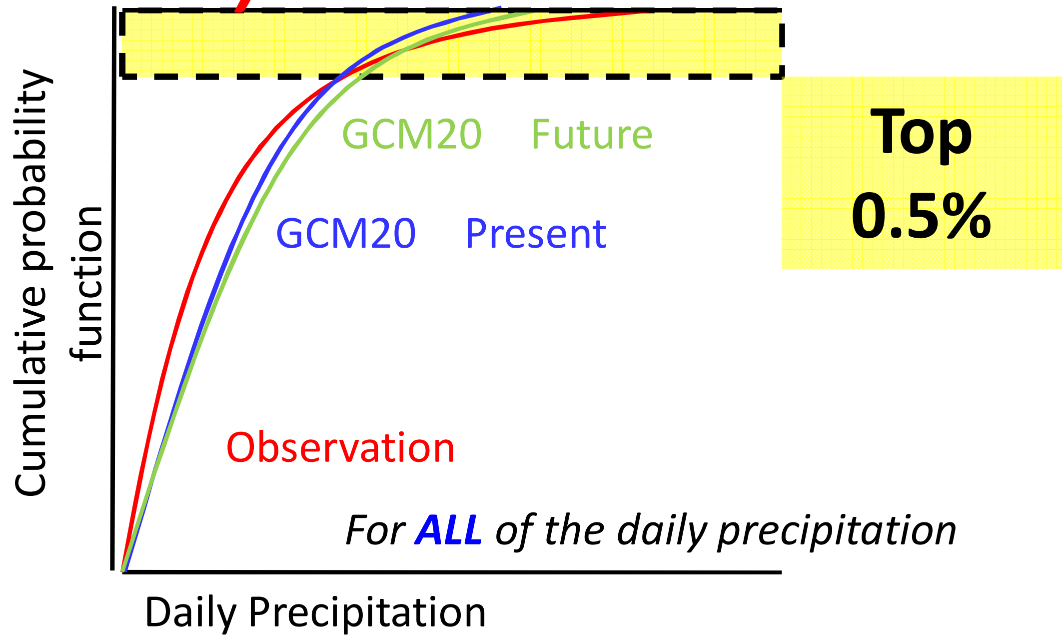
$$x'_{GCM}=F^{-1}\{F(x_{His};\alpha,\beta|_{His})\}$$

Concept of bias correction method for MRI GCM *(Hybrid Method)*

Remark: Inomata et al. (2011)

A) Extreme Value
⇒The samples in top 0.5% of prob. of non exceedance are considered.

B) Other value
⇒They are divided into each flood event.



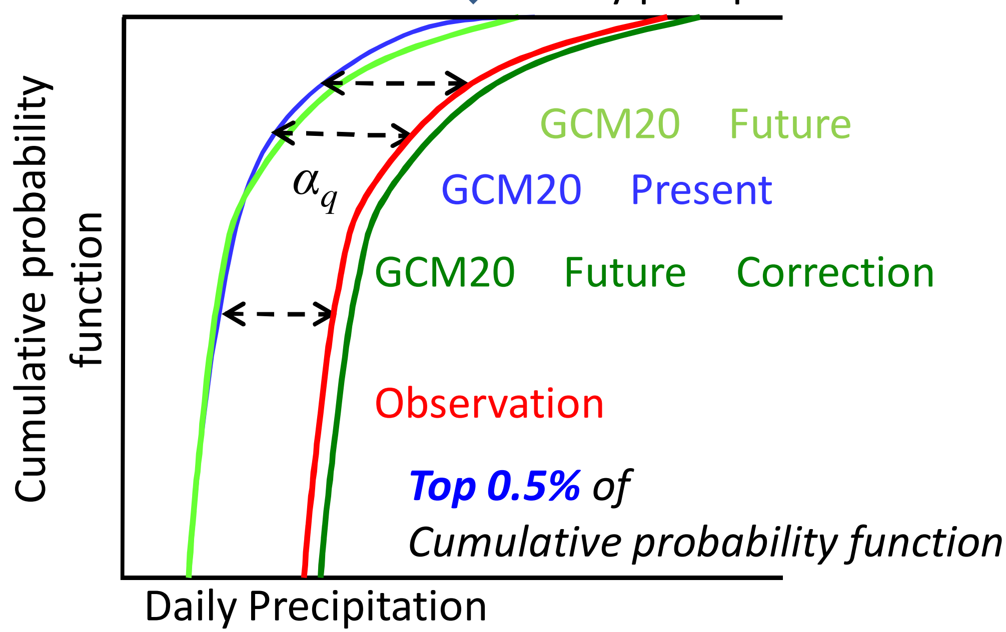
①The samples in top 0.5% on cumulative probability density function for observation, GCM20 Present and GCM20 Future are abstracted.

Abstraction of top 0.5% daily precipitation

②The ration for each quantile (α_q) between observation (P_Obs_q) and GCM20 Present ($GCM20\_Pre_q$) is estimated. α_q is regarded as a correction coefficient for each quantile and multiplied to the value of GCM20 Future of same quantile ($GCM20\_Fut_q$) and corrected value (P_Fut_q) is obtained.

$$\alpha_q = \frac{P\_Obs_q}{GCM20\_Pre_q}$$

$$P\_Fut_q = \alpha_q \times GCM20\_Fut_q$$



Concept of bias correction method for GCM20 (cont.)

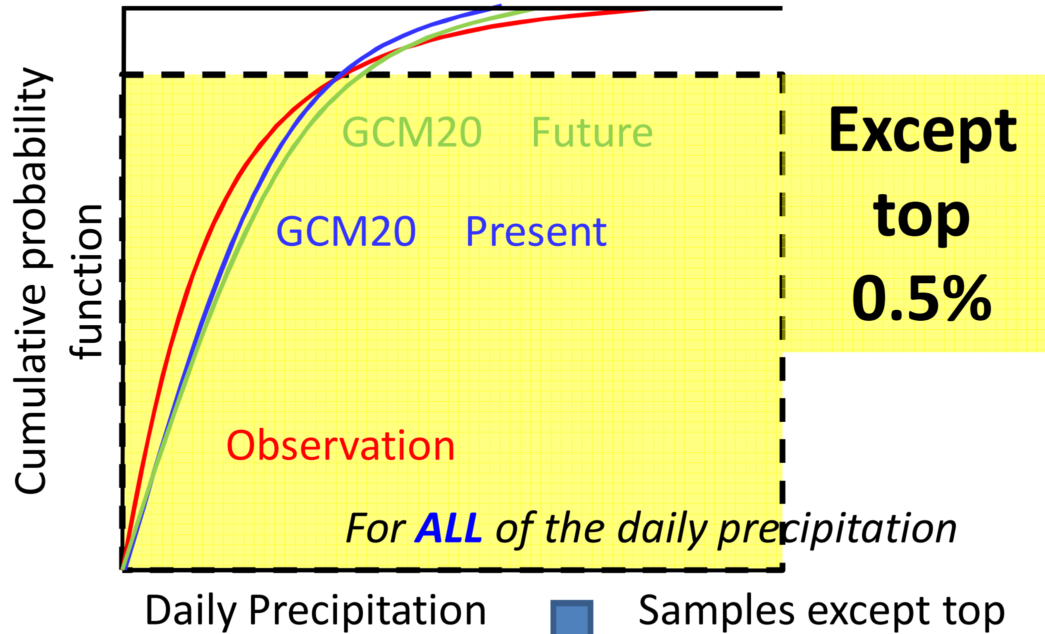
Hybrid Method **Ref: Inomata et al. (2011)**

③Samples except top 0.5% on observation, GCM20 Present and Future are divided into each month.

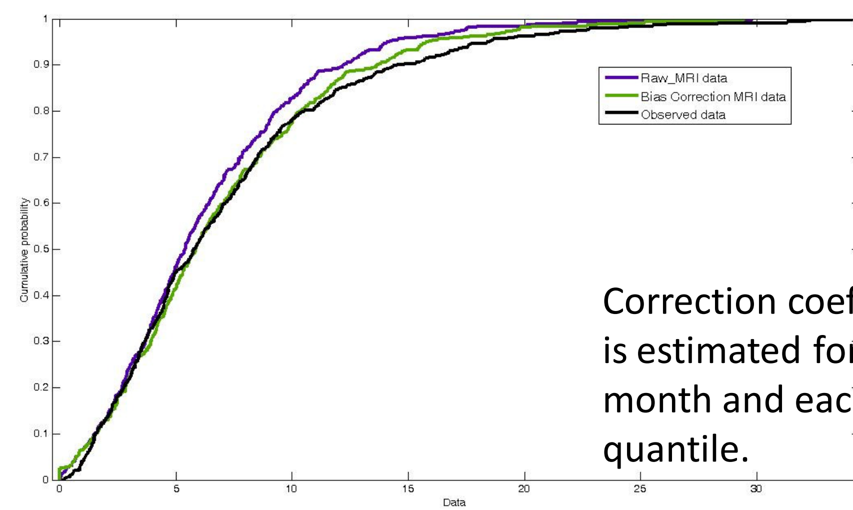
④The ratio between observation ($P\_Obs_{m\_q}$) and GCM20 Present ($GCM20\_Pre_{m\_q}$) is estimated for each flood event and each quantile (α_{m_q}). α_{m_q} is regarded as correction coefficient and multiplied to GCM20 Future of same flood event and same quantile ($GCM20\_Fut_{m\_q}$) and corrected value ($P\_Fut_{m\_q}$) is obtained.

$$\alpha_{m\_q} = \frac{P\_Obs_{m\_q}}{GCM20\_Pre_{m\_q}}$$

$$P\_Fut_{m\_q} = \alpha_{m\_q} \times GCM20\_Fut_{m\_q}$$

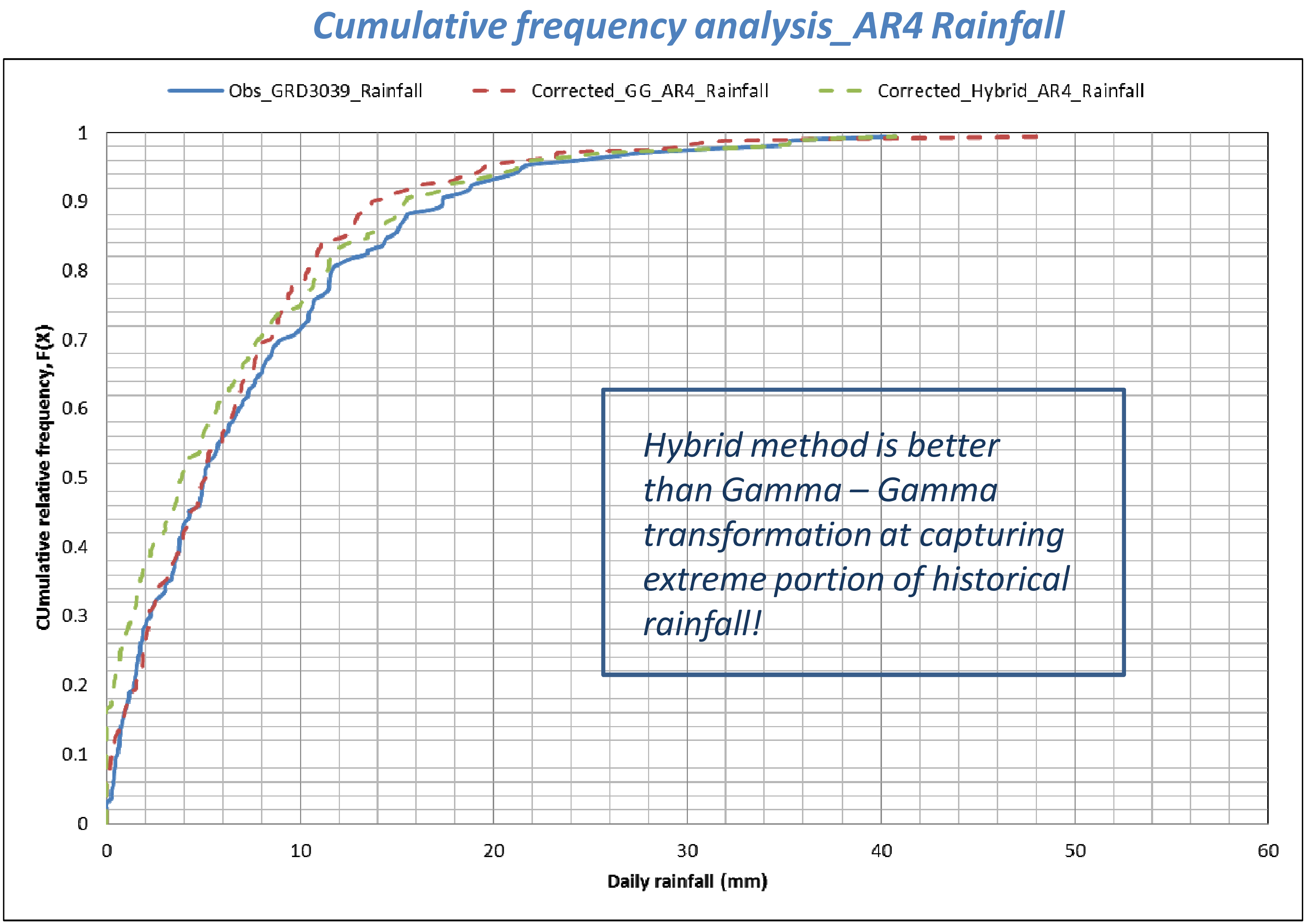


Samples except top 0.5% is divided into each month.



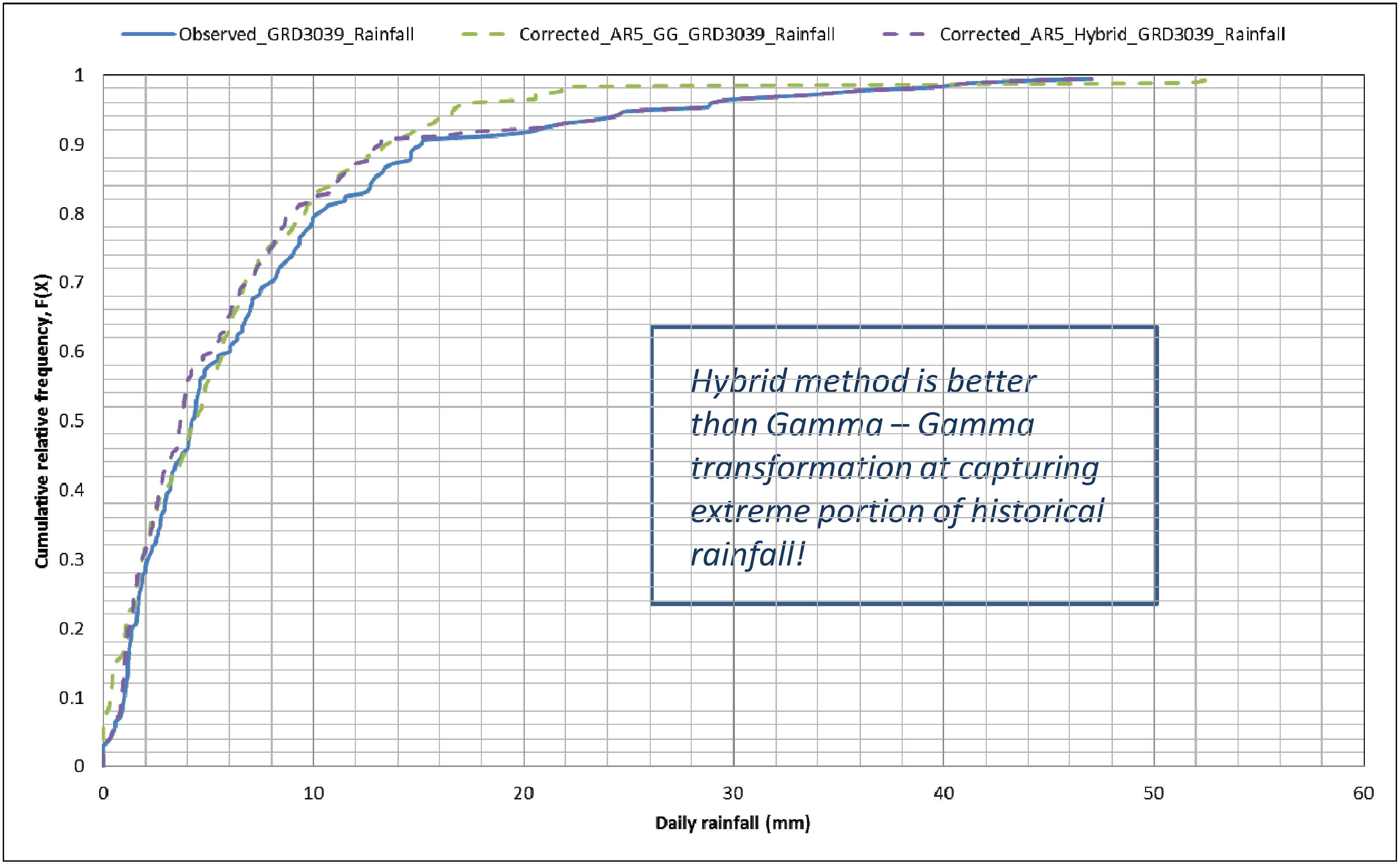
Correction coefficient is estimated for each month and each quantile.

Comparison of bias correction method



Comparison of bias correction method

Cumulative frequency analysis_AR5 Rainfall



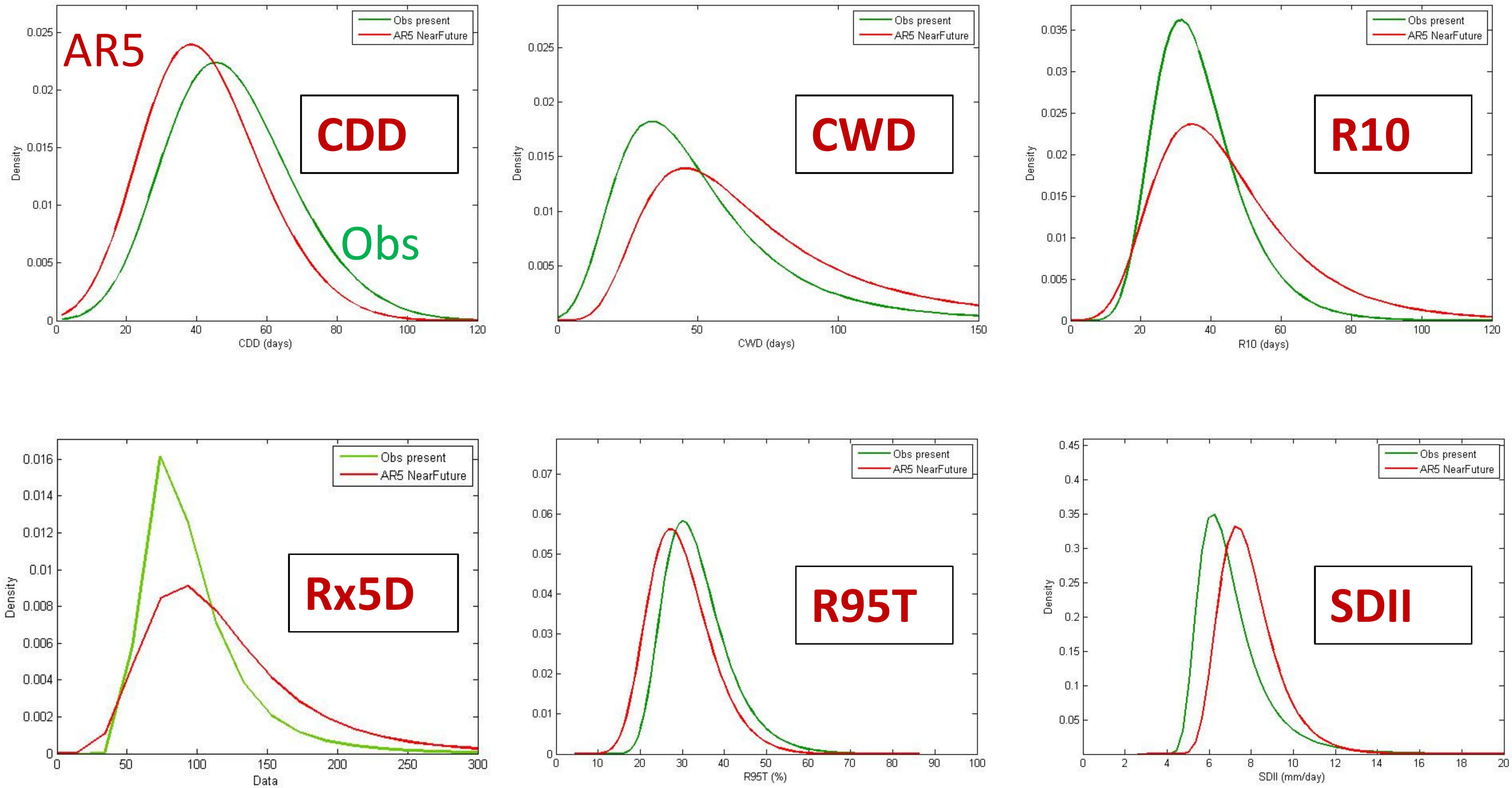
Extreme Precipitation Indices

Index	Definition	Unit
CDD	Maximum number of consecutive dry days (Rday < 1 mm)	Days
CWD	Maximum number of consecutive wet days (Rday $\geq$ 1 mm)	Days
R10	Number of days with precipitation $\geq$ 10 mm	Days
R20	Number of days with precipitation $\geq$ 20 mm	Days
Rx1Day	Maximum 1-day rainfall amount	mm
Rx5Day	Maximum 5-day rainfall amount	mm
SDII	Simple daily intensity index	mm/day
R95T	Fraction of 95^{th} percentile to annual precipitation	%

Projected Change in Extreme Indices

- Near future scenarios: 2015-2039
- Comparison between observation (1979-2006) and AR4 and AR5 (2015-2039)

Projected Change in Extreme Indices



PDF of generalized extreme values distribution

River Basin	Percentage change in near future (AR5)							
	Extreme Precipitation Indices							
	R10	R20	SDII	RX1D	RX5D	CWD	CDD	R95T
Salawin	34%	256%	42%	225%	63%	-35%	-17%	39%
Mekong	-32%	-51%	-6%	+ 50 %	25%	29%	-27%	3%
Kok	-32%	-51%	-6%	20%	-5%	29%	-27%	3%
Chi	17%	-51%	13%	50%	63%	29%	-5%	-4%
Mun	34%	-51%	13%	50%	10%	67%	-5%	-17%
Ping	34%	51%	23%	100%	63%	3%	-32%	39%
Wang	17%	51%	23%	100%	10%	29%	-32%	12%
Yom	17%	-16%	13%	50%	10%	29%	-27%	3%
Nan	17%	-16%	13%	75%	37%	29%	-22%	3%
Chao Phraya	52%	12%	13%	-46%	10%	387%	-5%	-48%
Sakaekrang	52%	51%	42%	75%	10%	24%	-5%	12%
Pasuk	17%	51%	4%	50%	-7%	-23%	-13%	12%
Tha Chin	91%	51%	23%	-46%	37%	204%	-32%	-48%
Mae Klong	145%	196%	52%	120%	63%	25%	-5%	23%
Prachinburi	17%	-16%	4%	-46%	-7%	107%	-5%	-25%
Bang Pakong	52%	-51%	13%	20%	-7%	204%	-13%	-25%
Tonle Sap	34%	51%	13%	50%	10%	107%	-5%	-17%

River Basin	Percentage change in near future (AR5)							
	Extreme Precipitation Indices							
	R10	R20	SDII	RX1D	RX5D	CWD	CDD	R95T
East-Coast Gulf	52%	-16%	23%	20%	-7%	153%	-13%	-35%
Phetchaburi	145%	322%	71%	100%	63%	-23%	-22%	12%
West-Coast Gulf	145%	396%	71%	163%	63%	-23%	-22%	12%
Peninsula-East Coast	52%	51%	42%	163%	200%	-23%	-27%	-17%
Tapi	116%	51%	42%	163%	125%	-23%	-32%	-17%
Thale sap Songkhla	52%	51%	23%	163%	63%	-23%	-32%	-35%
Pattani	70%	-16%	23%	163%	225%	68%	-46%	-35%
Peninsula-West Coast	52%	51%	23%	163%	225%	29%	-32%	-25%

Summary

- Hybrid Method provides appropriate bias correction of seasonal patterns and extreme daily rainfall
- MRI AGCMs can capture spatial patterns of extreme rainfall during 1979-2006 well
- Changes in extreme precipitation in the near future are complex
- Consistent trend in decrease in CDD and R95T
- Increase trend in CWD and rainfall intensity (R10, Rx5Day, SDII)

Evaluation of Satellite Rainfall Estimates for Application of Flood Simulation:

Case Study of Yom River Basin

Dr.Anurak Sriariyawat

Dr. Piyatida Hoisungwan

Kwanchai Pakoksong

Teerawat Ram-Indra

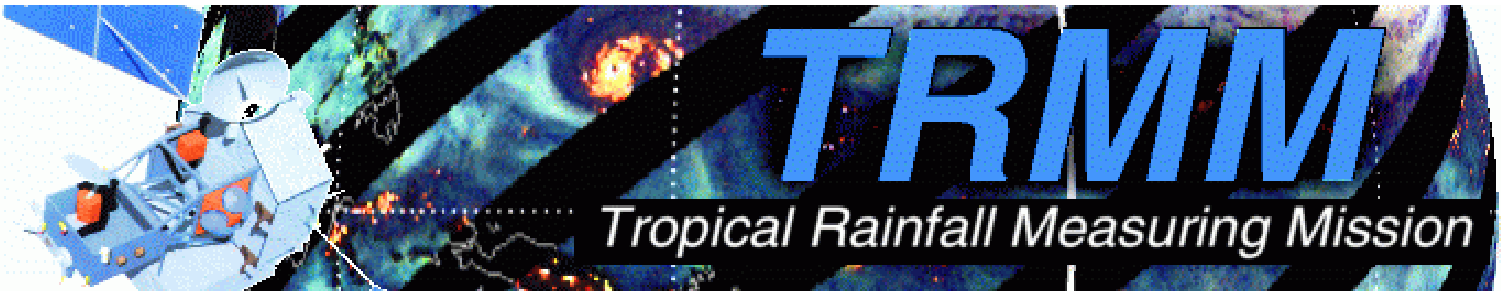
Department of Water Resources Engineering

Chulalongkorn University

AUN/SEED-Net Special Research Program for Disaster Prevention and Mitigation (SDM)

Outline

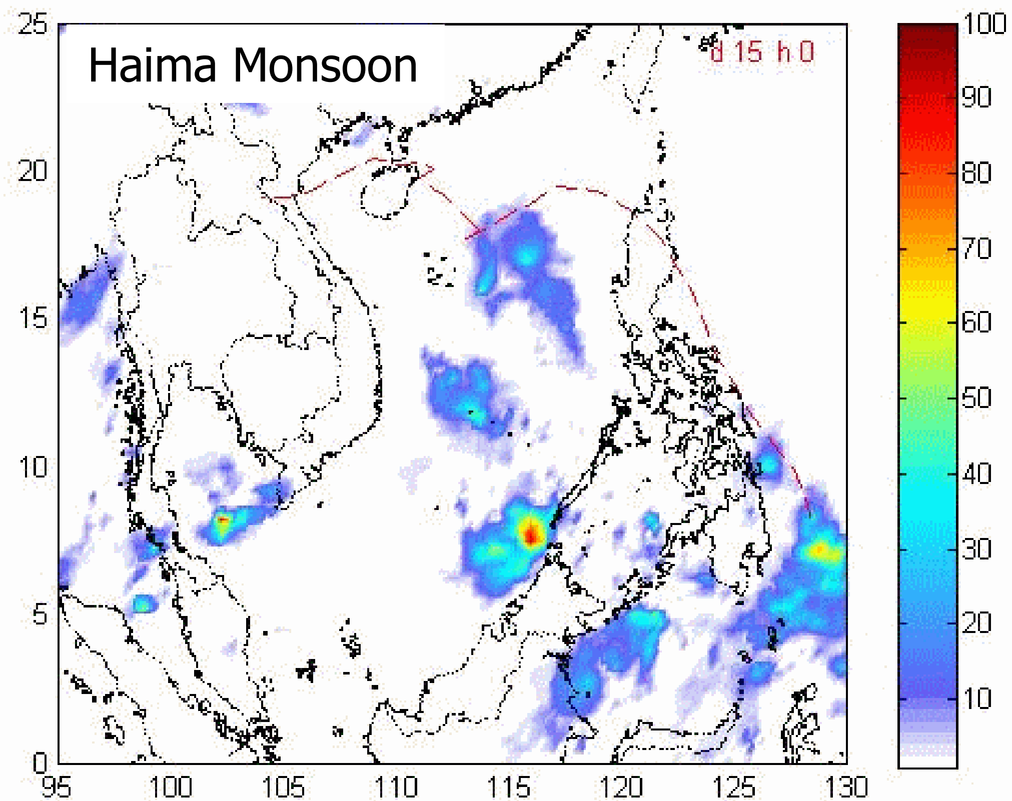
- Satellite-based rainfall estimates (TRMM v7 3B42)
- Comparison with rain-gage observations
- Bias correction techniques
- Flood simulation case study: Yom River Basin



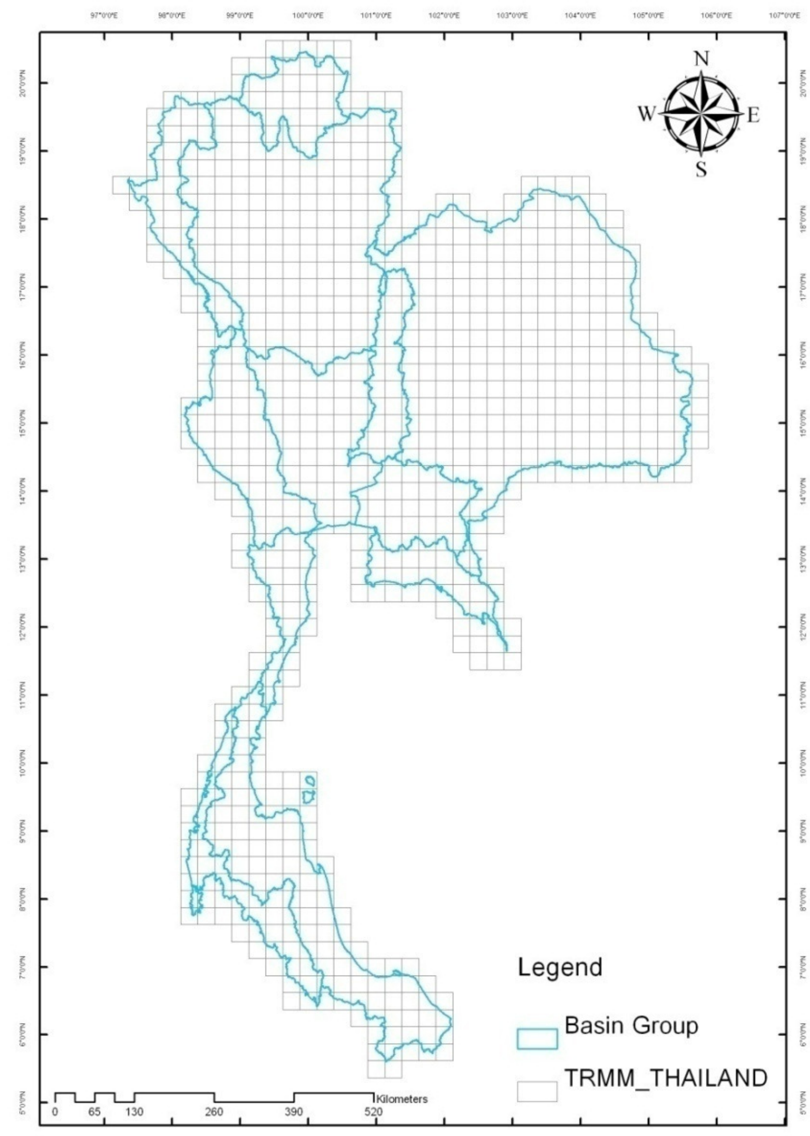
By NASA data service 3 hourly From 1998 – present

pixel size 0.25 x 0.25 degree

The V7 3B42 product based on multi-satellite precipitation analysis. [Huffman et al, 2007]



http://trmm.gsfc.nasa.gov



Power Transformation

$$TRMM_{adj} = a * TRMM^{b}$$

Objective function : minimize **RMSE** between *Obs.* and $TRMM_{adj}$ where

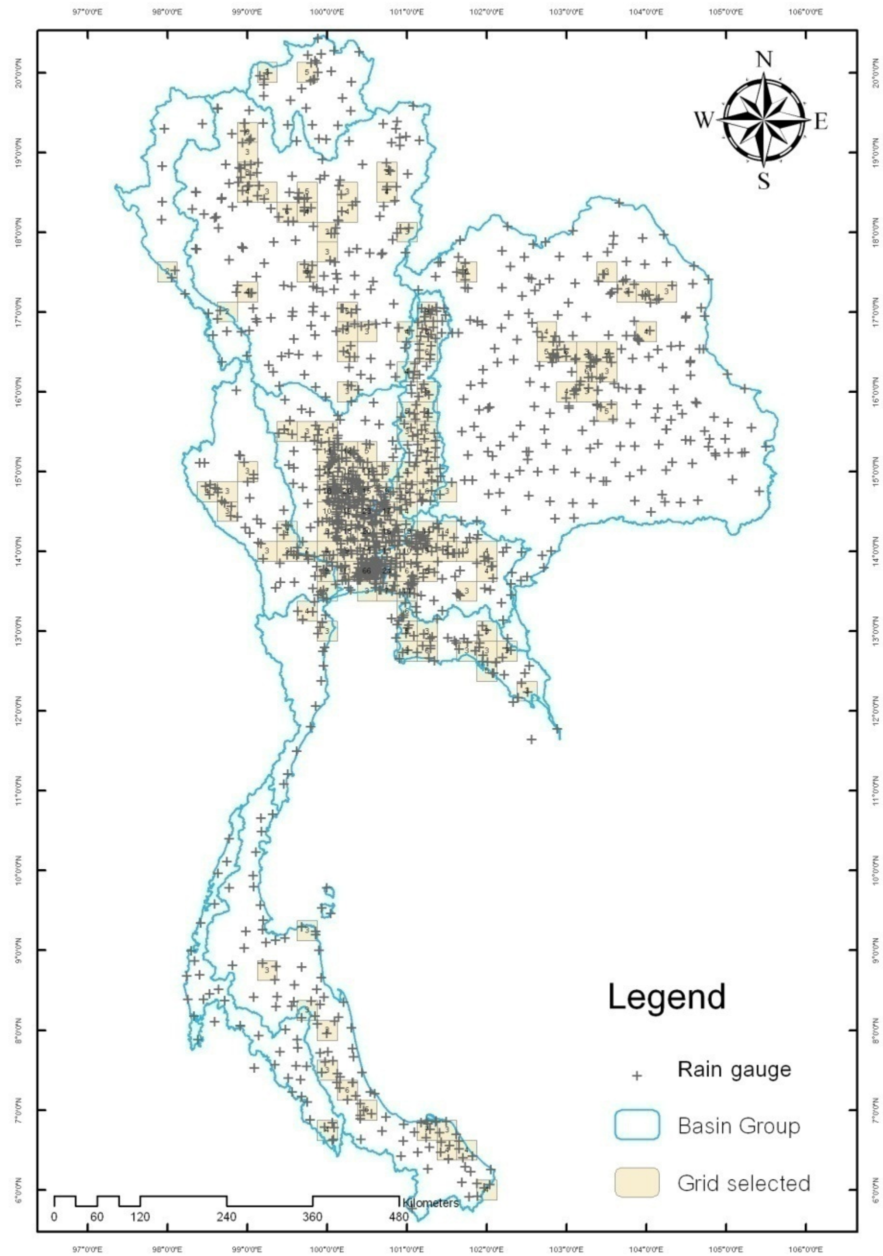
$TRMM_{adj}$ = Bias corrected TRMM, mm

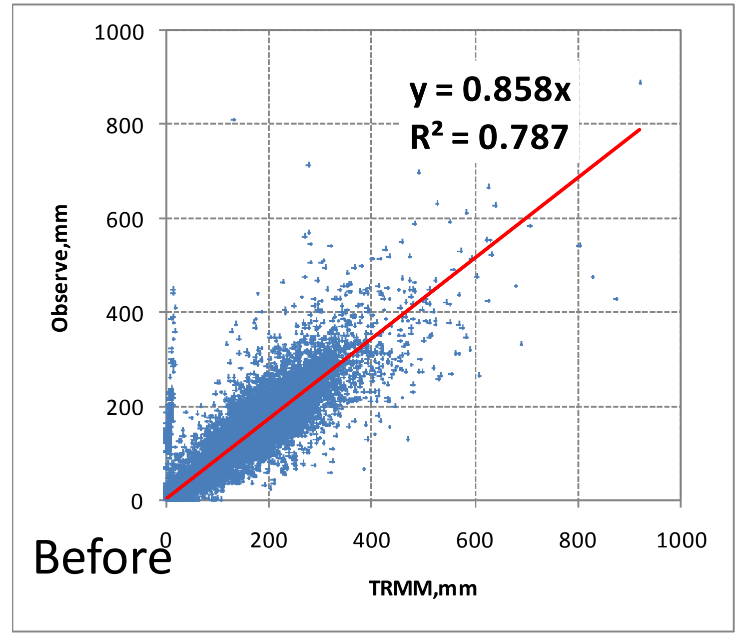
a = parameter, mm

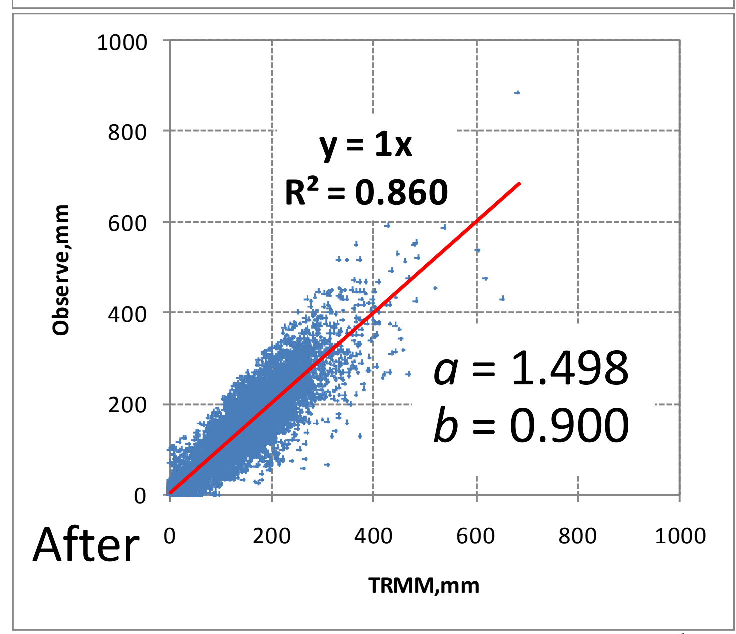
b = parameter dimensionless

[Vernimmen et al., 2012]

Bias Correction of Monthly Rainfall of Selected Grids

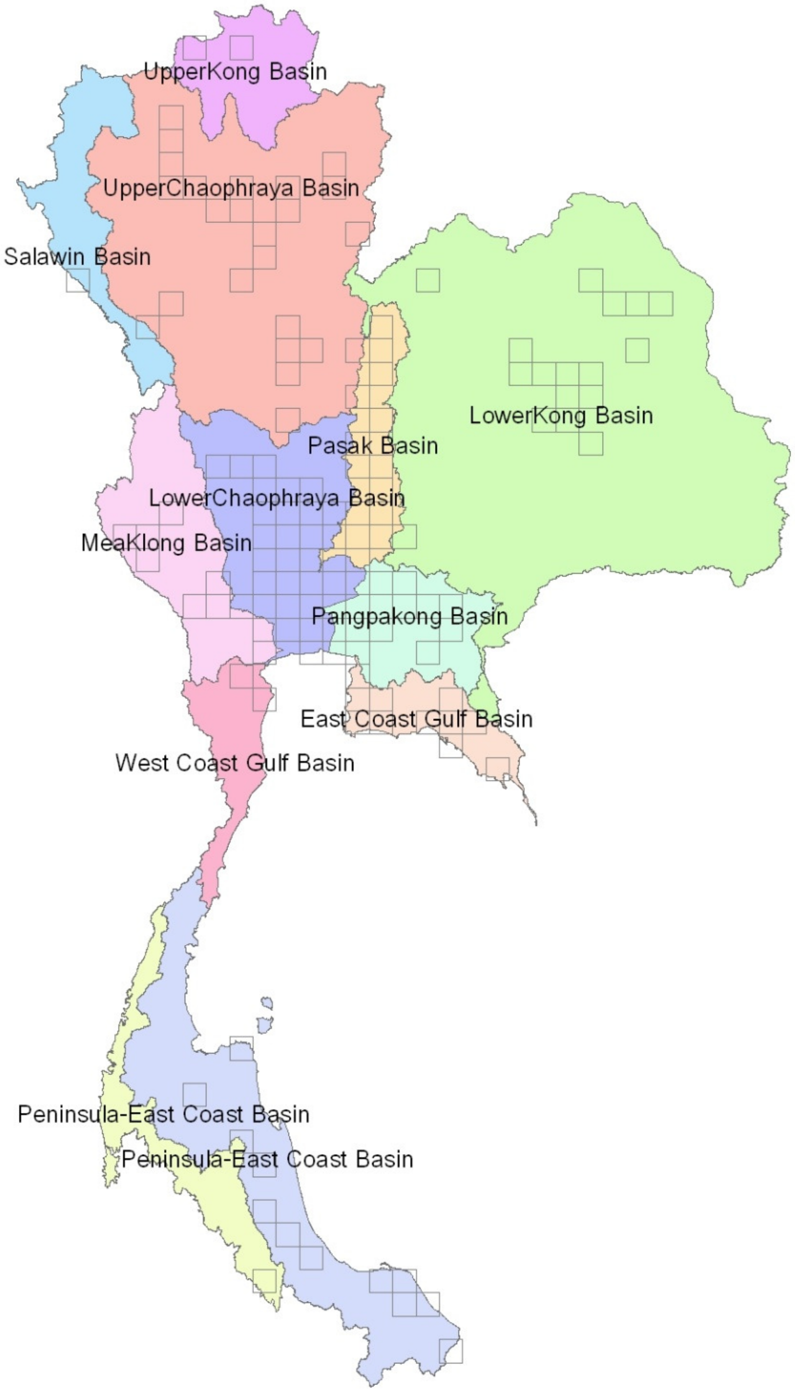






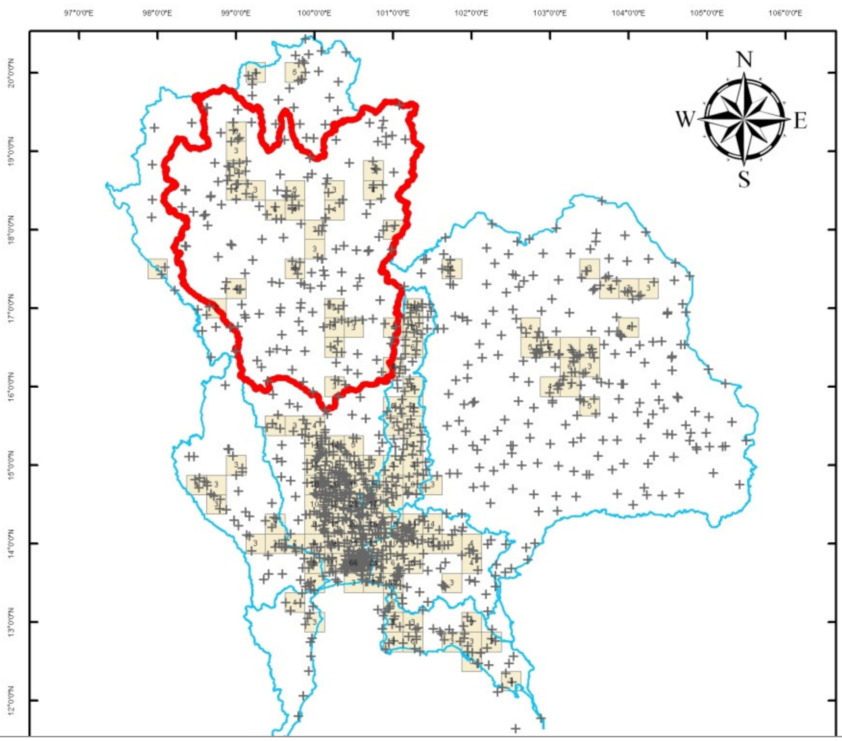
$$TRMM_{adj} = a * TRMM^{b}$$

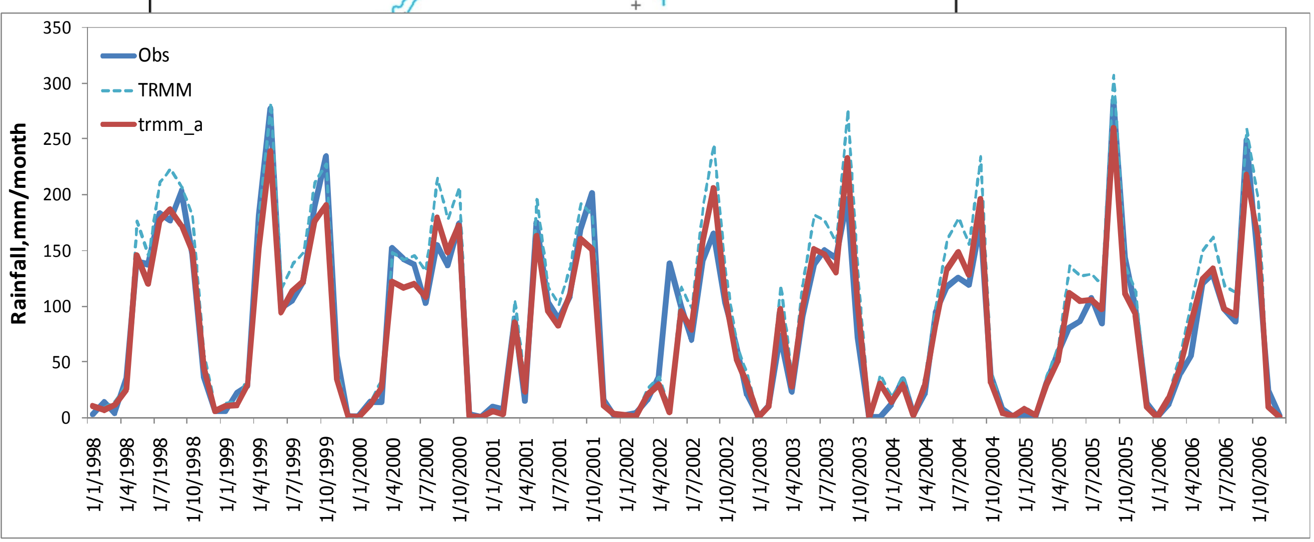
Calibrated Parameters for Each Basin

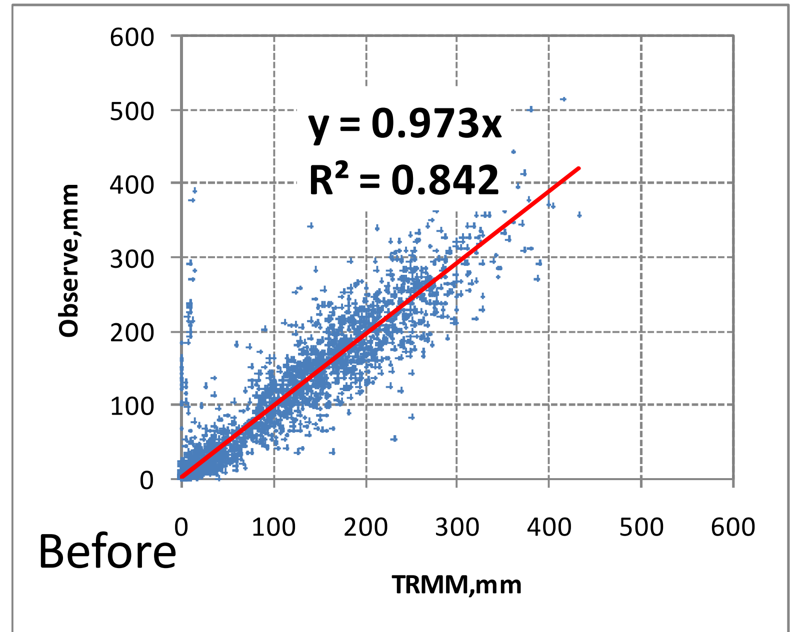


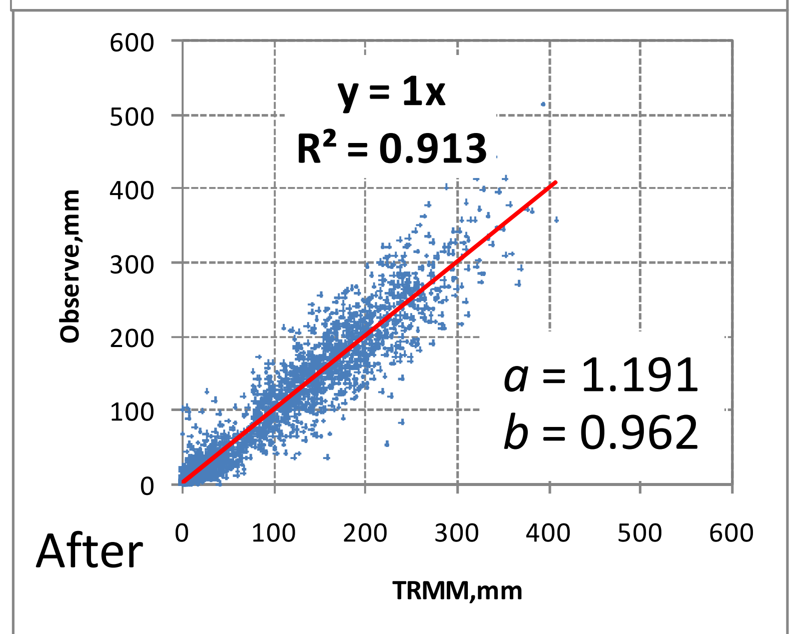
Basin Group	*a*	*b*	R^2
1.UpperKong	3.084	0.784	0.780
2.LowerKong	1.418	0.899	0.818
3.Salawin	2.789	0.798	0.855
4.UpperCPY	1.191	0.962	0.913
5.Pasak	1.388	0.908	0.783
6.LowerCPY	0.687	1.037	0.825
7.Pangpakong	2.678	0.783	0.428
8.Meaklong	2.683	0.809	0.347
9.East Coast Gulf	0.795	1.004	0.643
10.West Coast Gulf	6.345	0.626	0.598
11.Peninsula East	7.285	0.608	0.449
12.Peninsula West	5.385	0.670	0.516

Bias Correction in Upper Chaophraya Basin





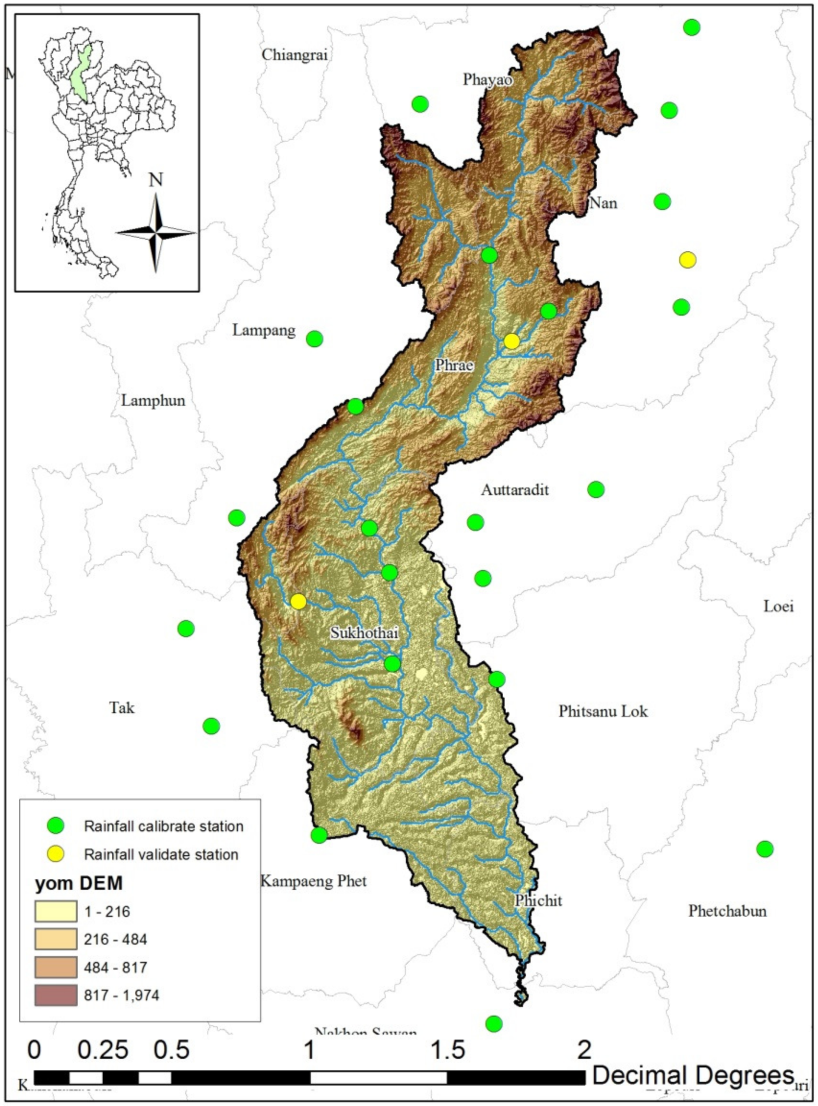


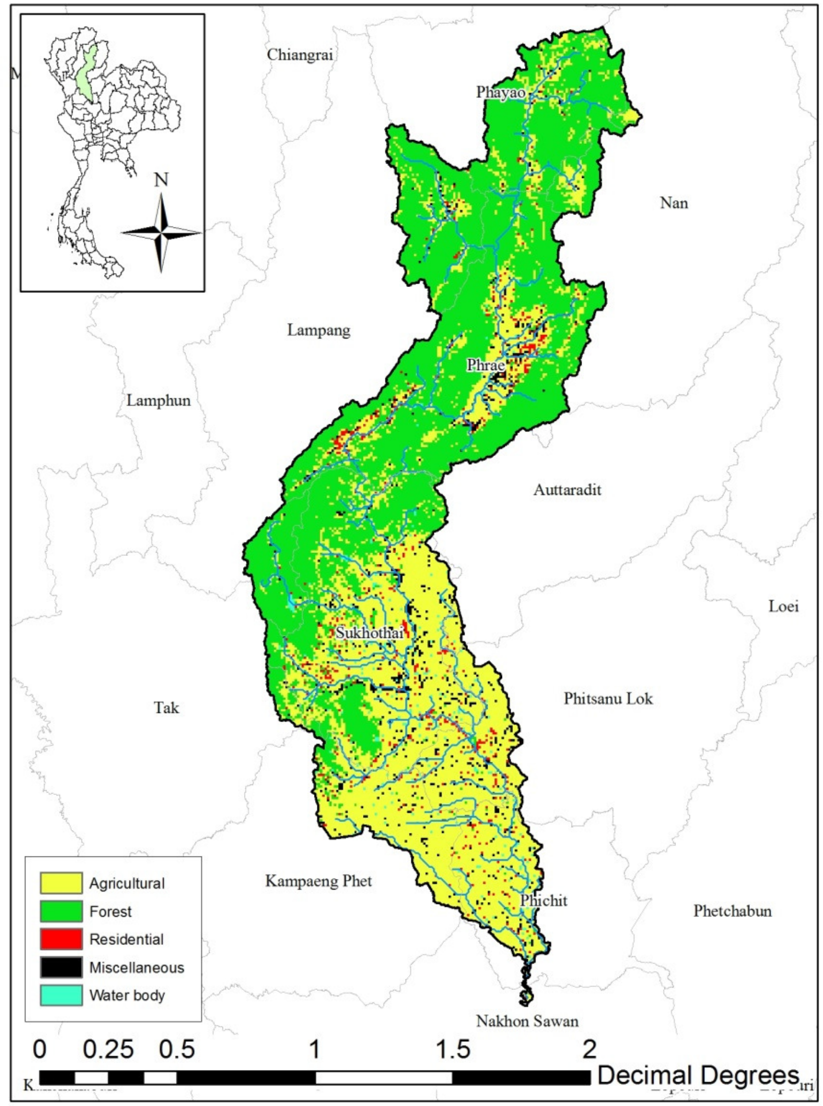


$$TRMM_{adj} = a * TRMM^{b}$$

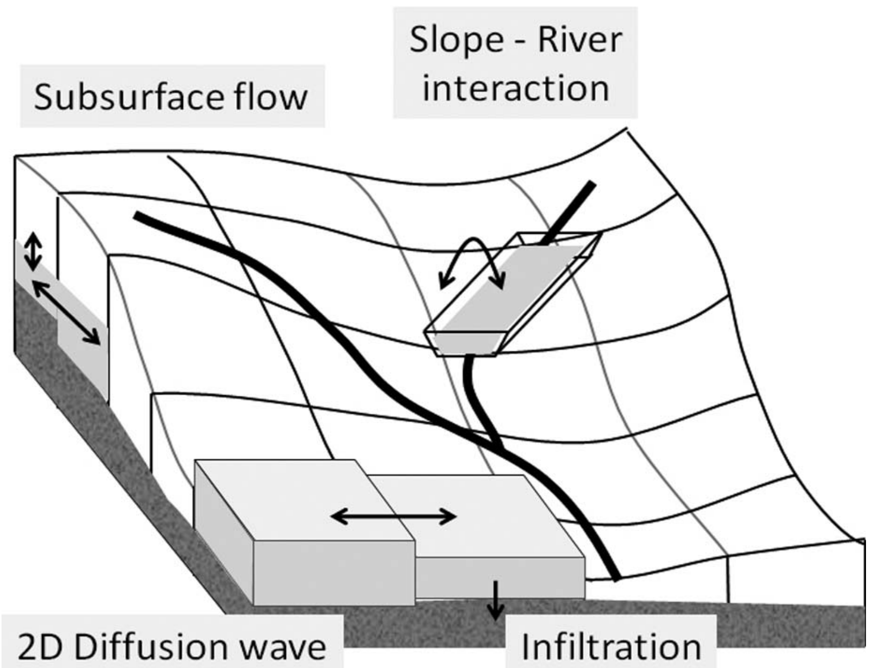
Flood Simulation Case Study

Yom River Basin





Rainfall-Runoff-Inundation Model

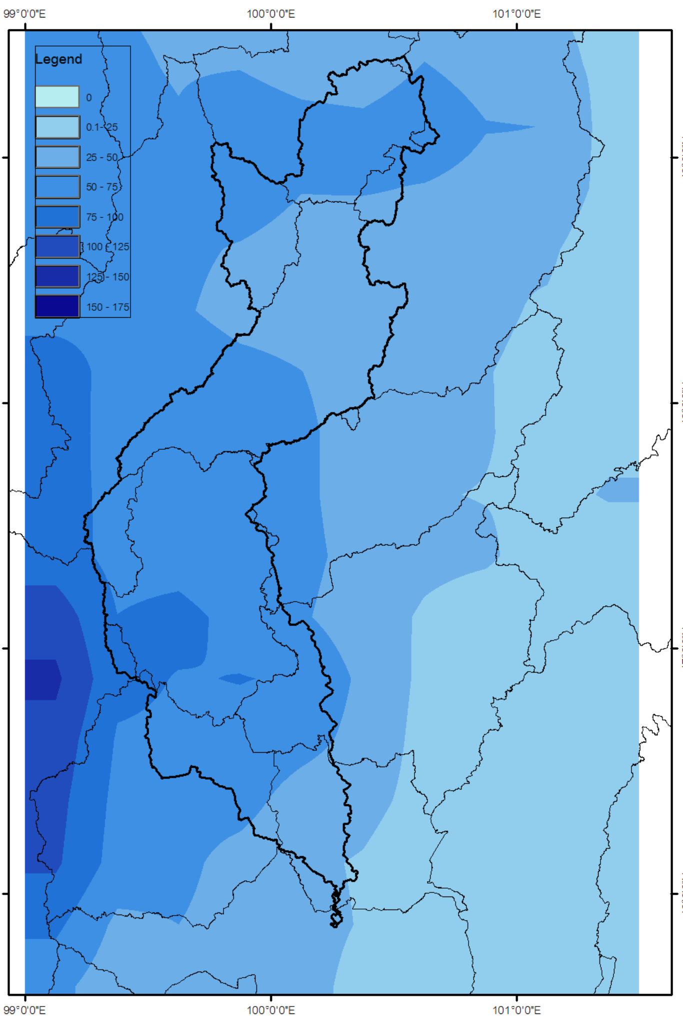


schematic diagram of the rainfall–runoff– inundation (RRI) model (Sayama et al., 2012).

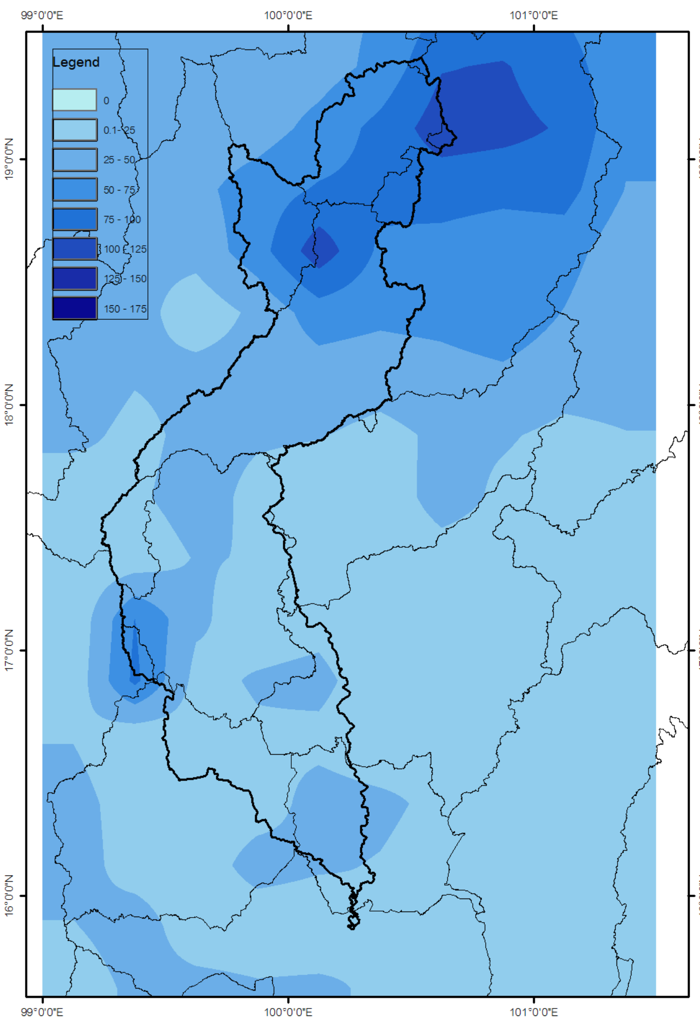
A two dimension Rainfall-Runoff-Inundation (RRI) model deals with slopes and river channels separately. The river channel is located on the grid cell while the model assumes that both slope and river are positioned within the same grid cell. A channel is discretized as a single vector along its centerline of the overlying slope grid cell. Lateral flows are simulated on slope cells on a two dimensional basis. The inflow-outflow interaction between the slope and river is calculated based on different overflowing formulae depending on water-level and levee-height conditions.

Spatial Bias Correction of Daily TRMM rainfall

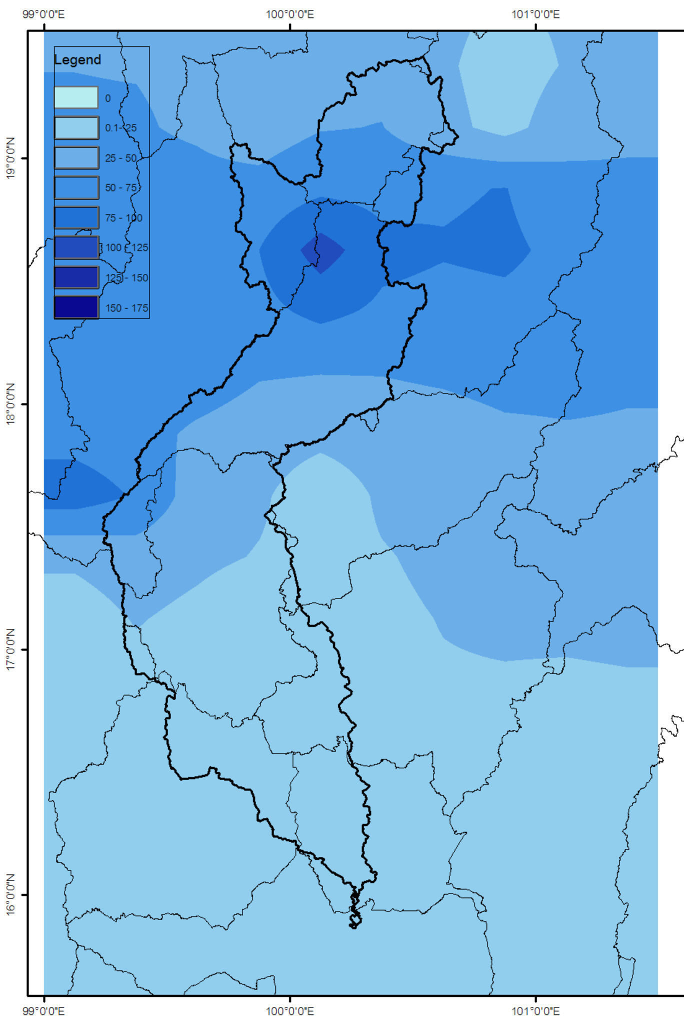
Uncorrectd TRMM



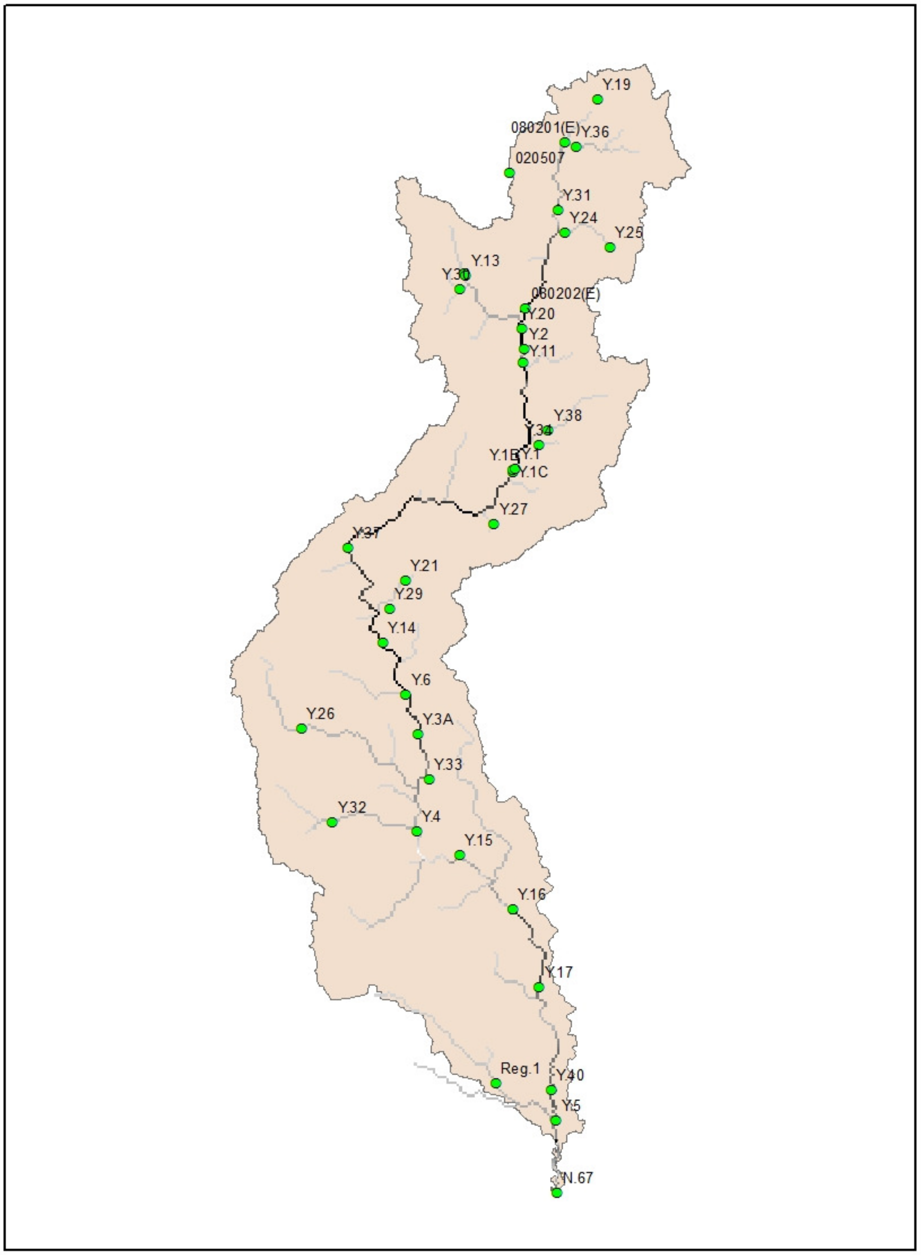
Correctd TRMM

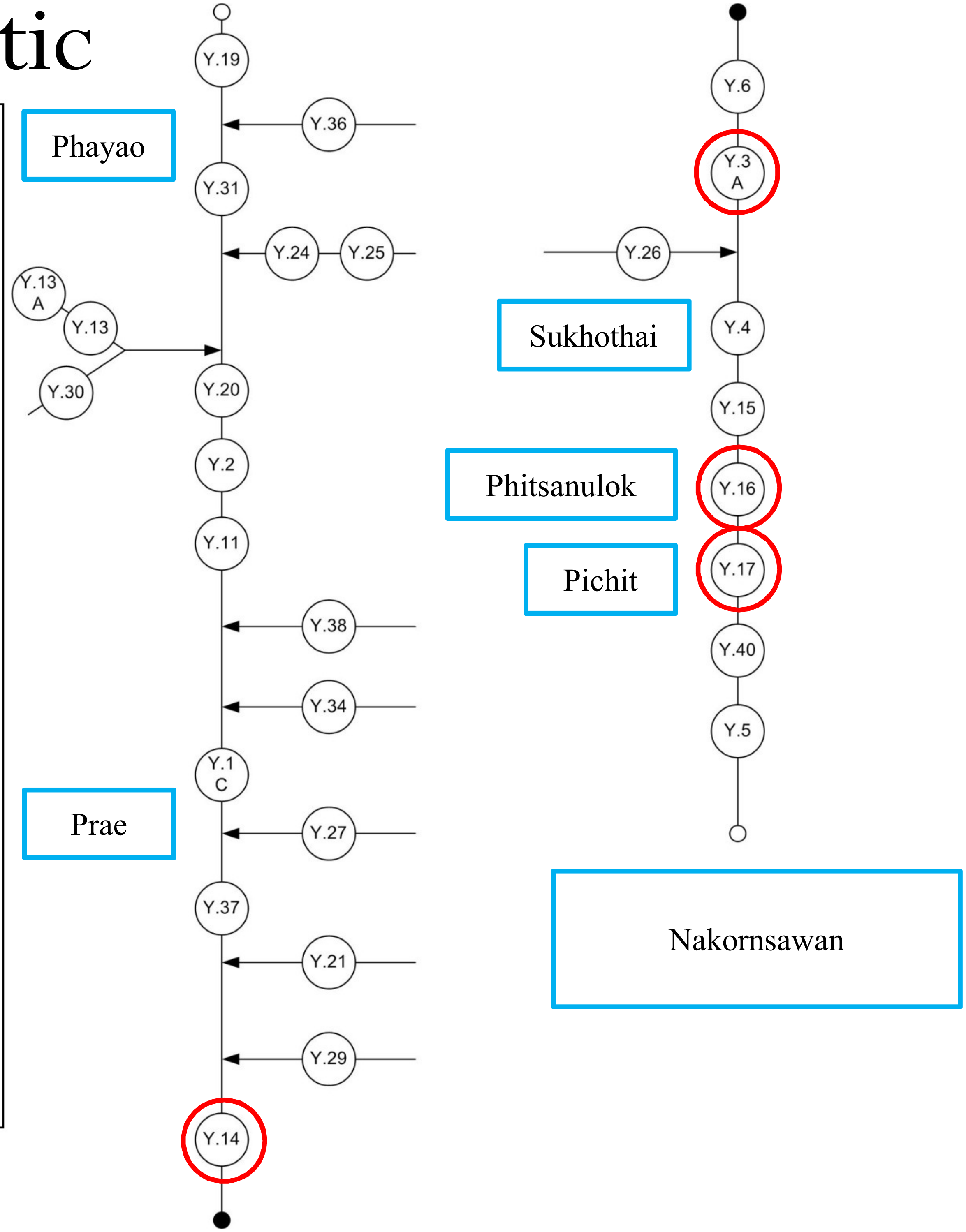


Station IDW



Yom River Schematic





Flow Verification (2012) at Y.14 Station