Impact of climate change on hydrology and water resource in Taiwan

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Outline

- **Impact of hydrology**
- **Impact on the water resource**

- Part I Impact on hydrology

Data period

1970-2009	1970-1989	1990-2009

Probability Distribution

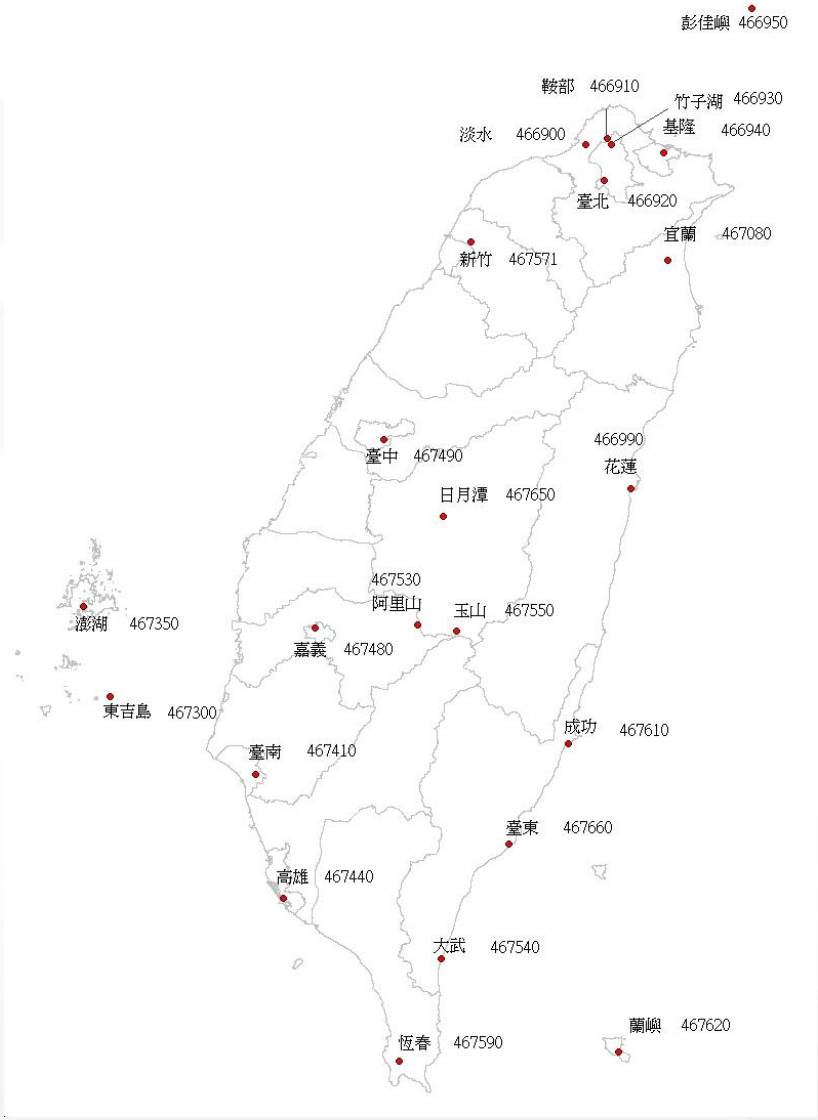
Normal	Log normal (2 parameters	GEV	EV I (Gumbel)	Pearson Type III	Log Pearson Type III

Parameter estimation

maximum likelihood

Goodness of fit

SLSC (standard least squares criterion)



CWB 23 gauging stations historical data

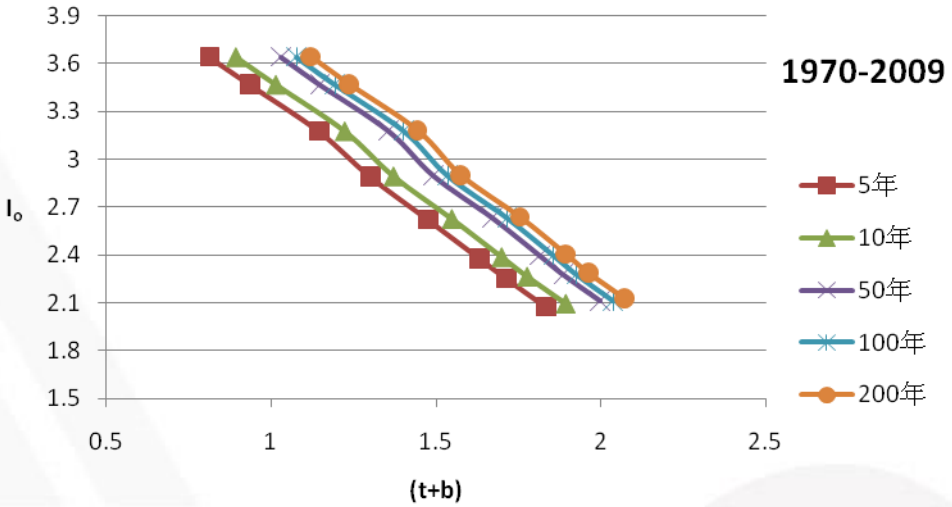
1970-2009

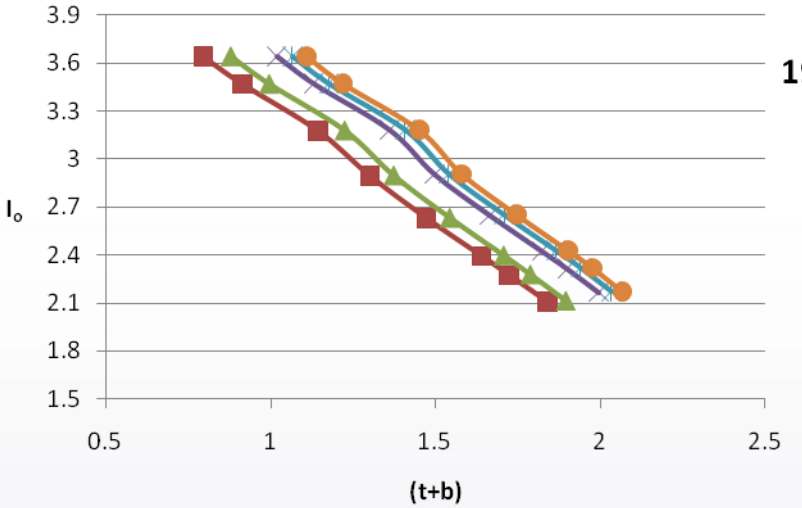
1970-1989

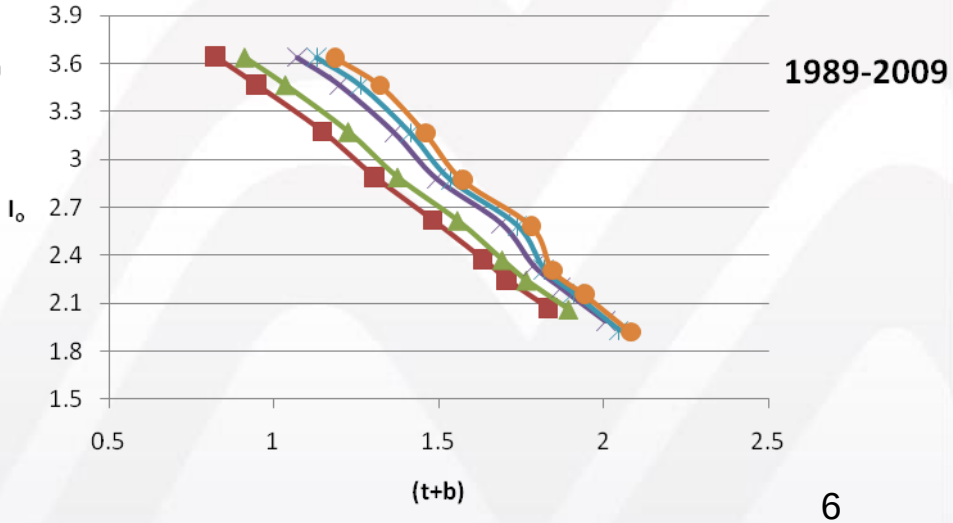
1989-2009

Trend and Frequency Analysis

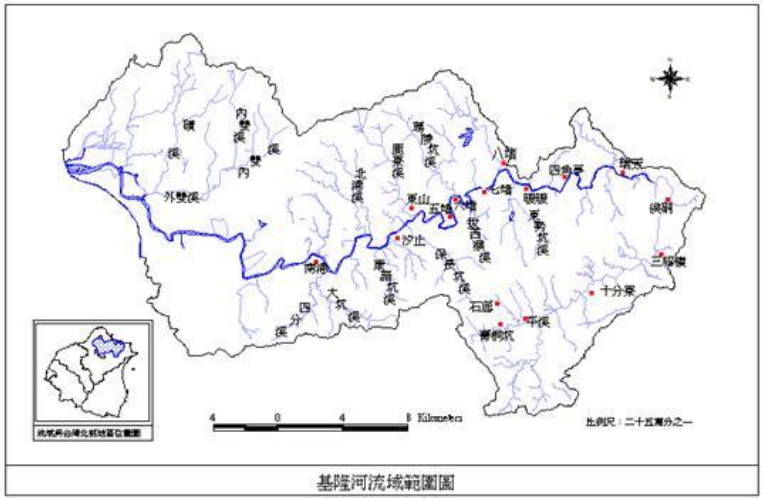
Horner equation $I_t = \frac{a}{(t+b)^c}$ IDF curve







Results example: River flow assessment



基隆河流域範圍圖

Basin name: Keelung River Basin
Area: 204.65 km^2
Main stream length: 49.152 km
Average elevation: 238.6 m
Average slope: 0.24

Return period used for assessment: 100 years
Model used for assessment: KW-GIUH & IFAS

國立臺灣海洋大學河海工程學系
集水區水文與水力研究室
Watershed Hydrology and Hydraulic Laboratory
Department of River and Harbor Engineering, National Taiwan Ocean University

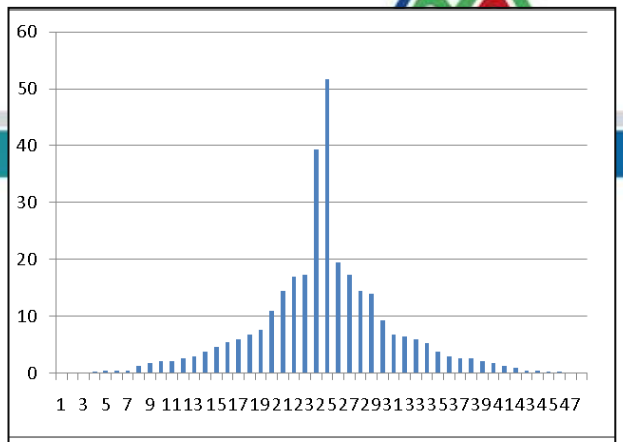
ICHARM IFAS

1987
LYNN

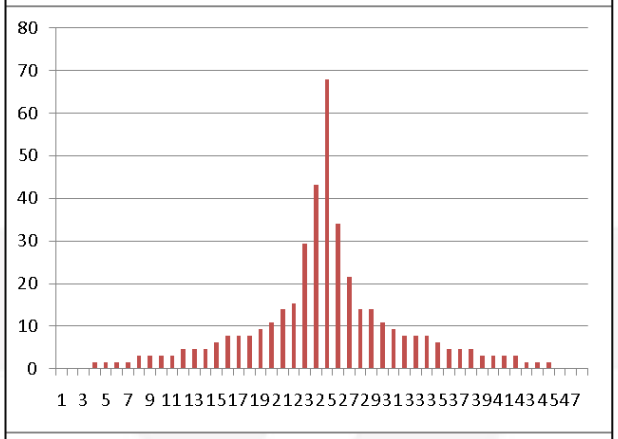
2009
MORAKOT

Design rainfall

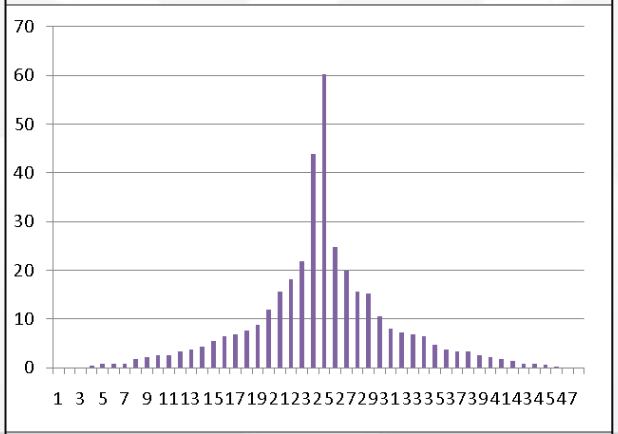
1970-1989

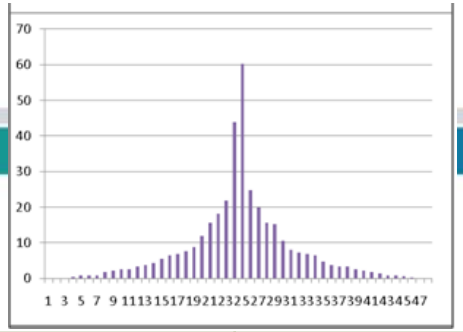


1989-2009



1970-2009

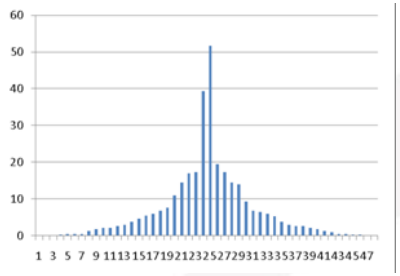


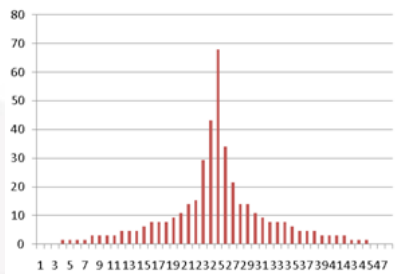


Same design rainfall

model	basin	Duration 24 hours			Duration 48 hours		
		1970-1989	1990-2009	1970-2009	1970-1989	1990-2009	1970-2009
KW-GIUH	Keelung river (Wutu)	1	0.91	1.01	1	1.38	1.14
IFAS		1	1.23	1.08	1	1.40	1.14

Different design rainfall

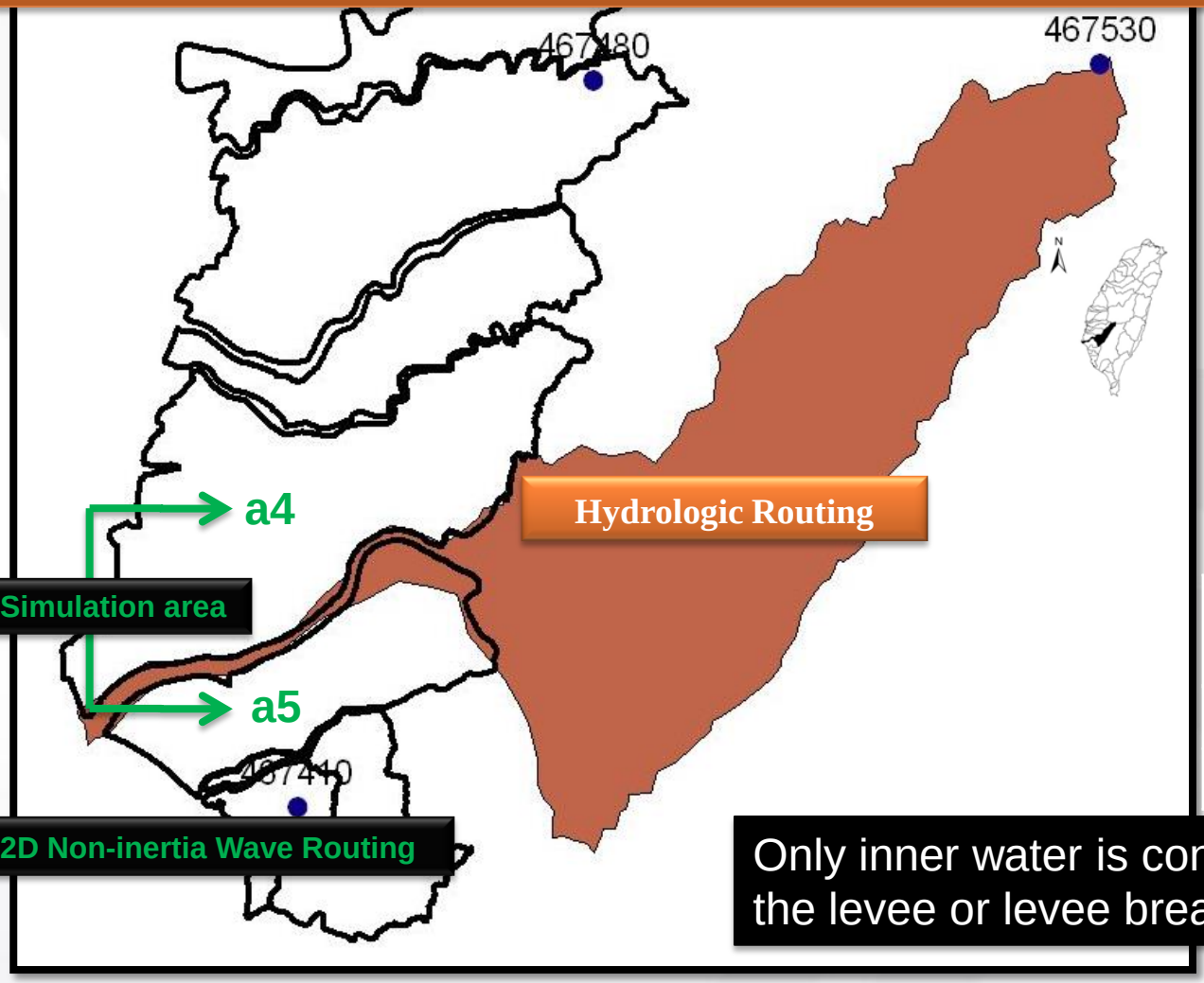




model	basin	Duration 24 hours			Duration 48 hours		
		1970-1989	1990-2009	1970-2009	1970-1989	1990-2009	1970-2009
KW-GIUH	Keelung river (Wutu)	1	1.82	1.14	1	2.18	1.25
IFAS		1	1.73	1.14	1	2.40	1.29

Result example: Inundation assessment

- mountainous area: by using HEC-1 model to calculate the surface runoff
- main stream: by routing 1D dynamic channel-flow model
- alluvial plain: 2D (non-inertia wave) overland flow routing

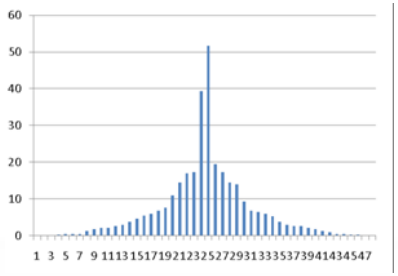


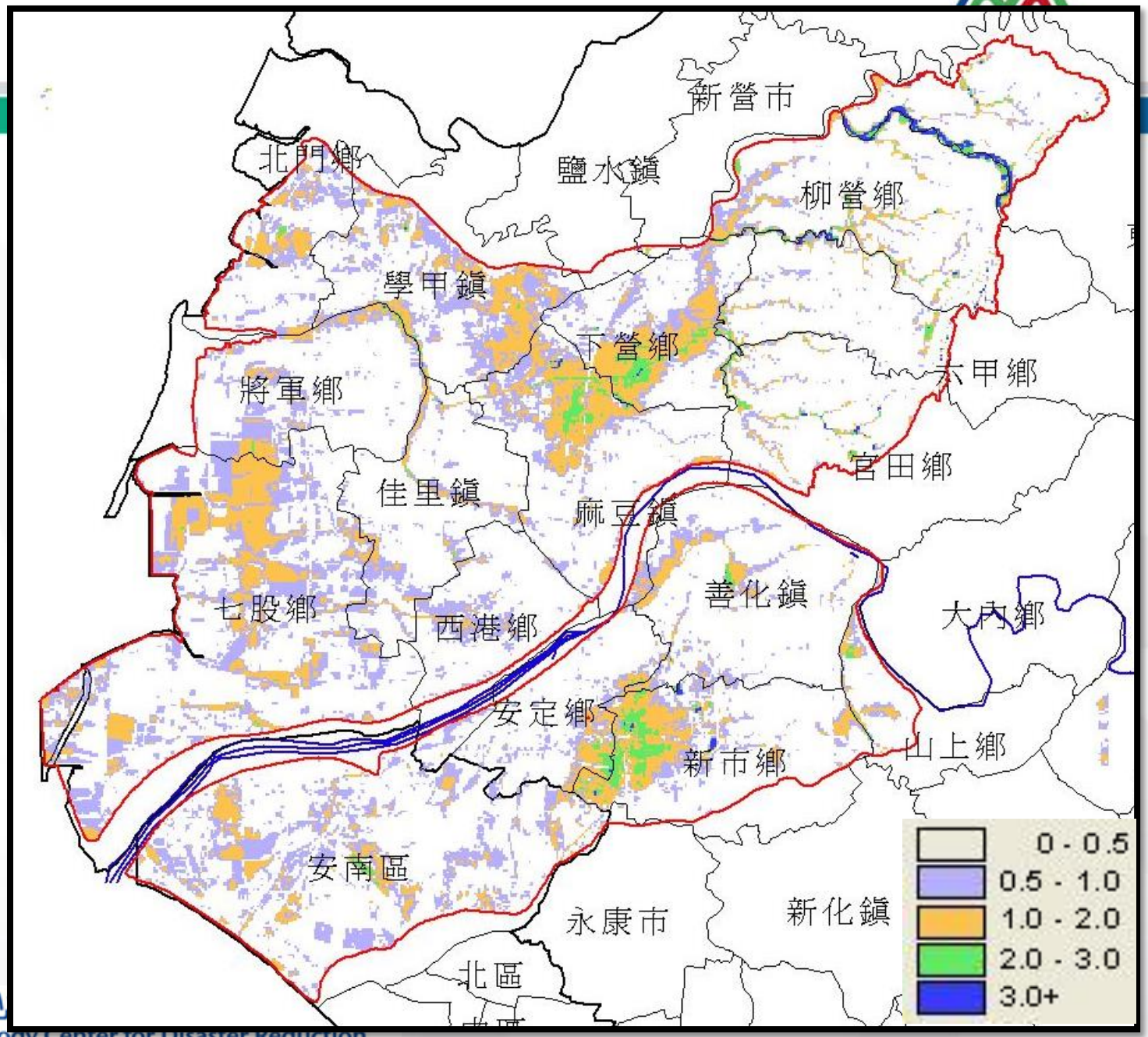
Part of Tainan county

simulation area	area (ha)
a4	49832.96
a5	23299.84

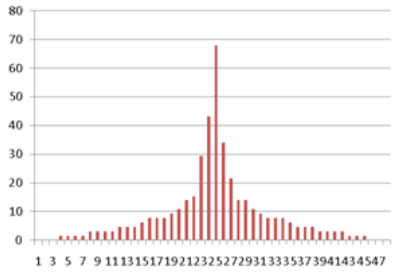
Only inner water is considered, overtopping of the levee or levee breaking is not included.

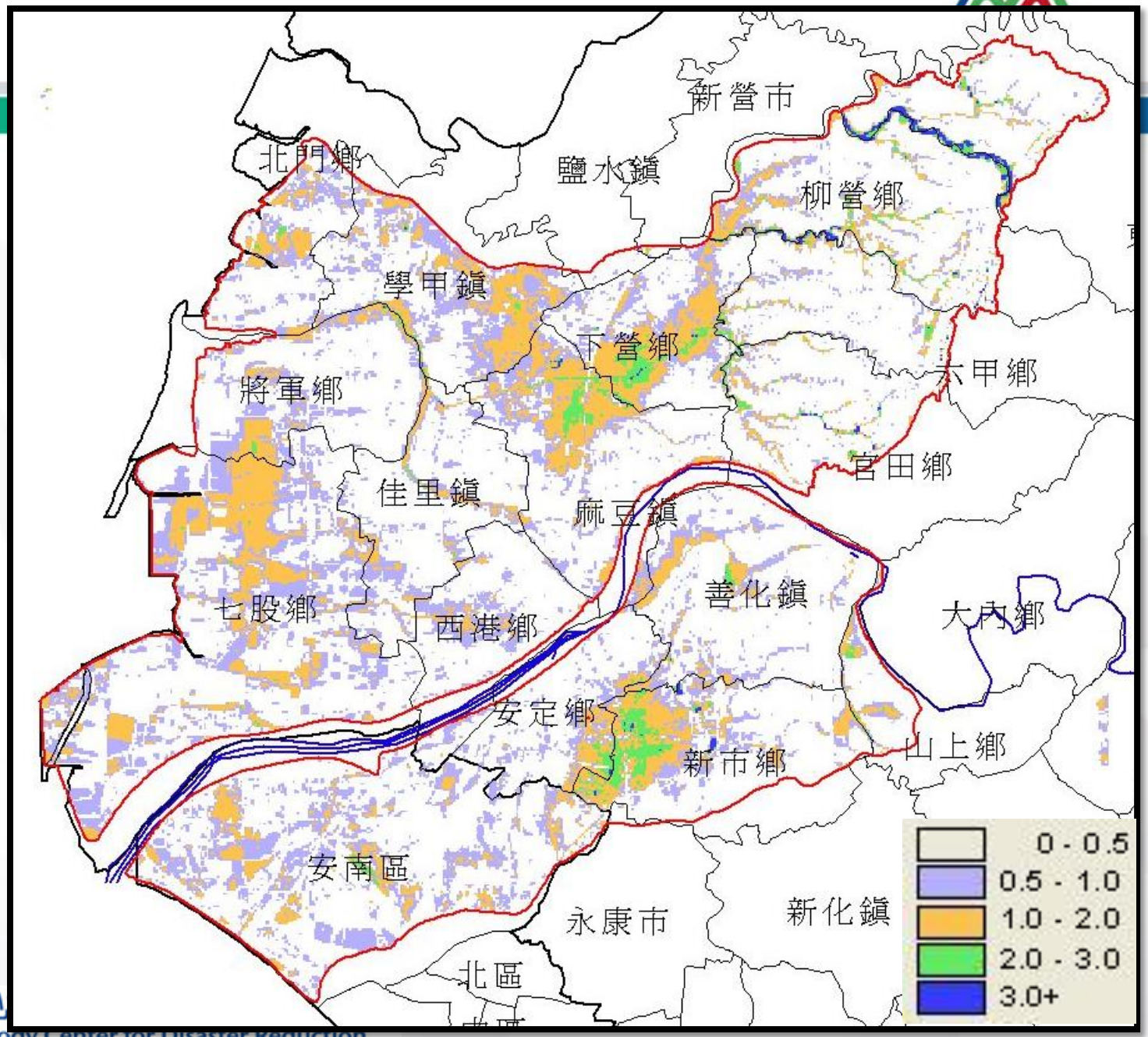
1970-1989


60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47


新營市
北門鄉
鹽水鎮
柳營鄉
學甲鎮
下營鄉
六甲鄉
將軍鄉
官田鄉
佳里鎮
麻豆鎮
善化鎮
七股鄉
西港鄉
大內鄉
安定鄉
山上鄉
新市鄉
安南區
永康市
新化鎮
北區
0 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0+

1990-2009


80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47


新營市
北門鄉
鹽水鎮
柳營鄉
學甲鎮
下營鄉
六甲鄉
將軍鄉
官田鄉
佳里鎮
麻豆鎮
善化鎮
七股鄉
西港鄉
大內鄉
安定鄉
新市鄉
山上鄉
安南區
永康市
新化鎮
北區
0 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0+

Inundation area*

area (ha)	1970-1989	1990-2009	(1990-2009)-(1970-1989) / (1970-1989)
0.5-1.0 m	13221.12	14817.28	12.07%
1.0-2.0 m	8216.32	9230.08	12.34%
2.0-3.0 m	1160.96	1356.16	16.81%
3.0+ m	309.12	346.24	12.01%
Total area	22907.52	25749.76	12.41%
Inundated area /total area (%)	31%	35%	

*：The area is the summation of simulation area a4 and a5

Conclusions and Future work

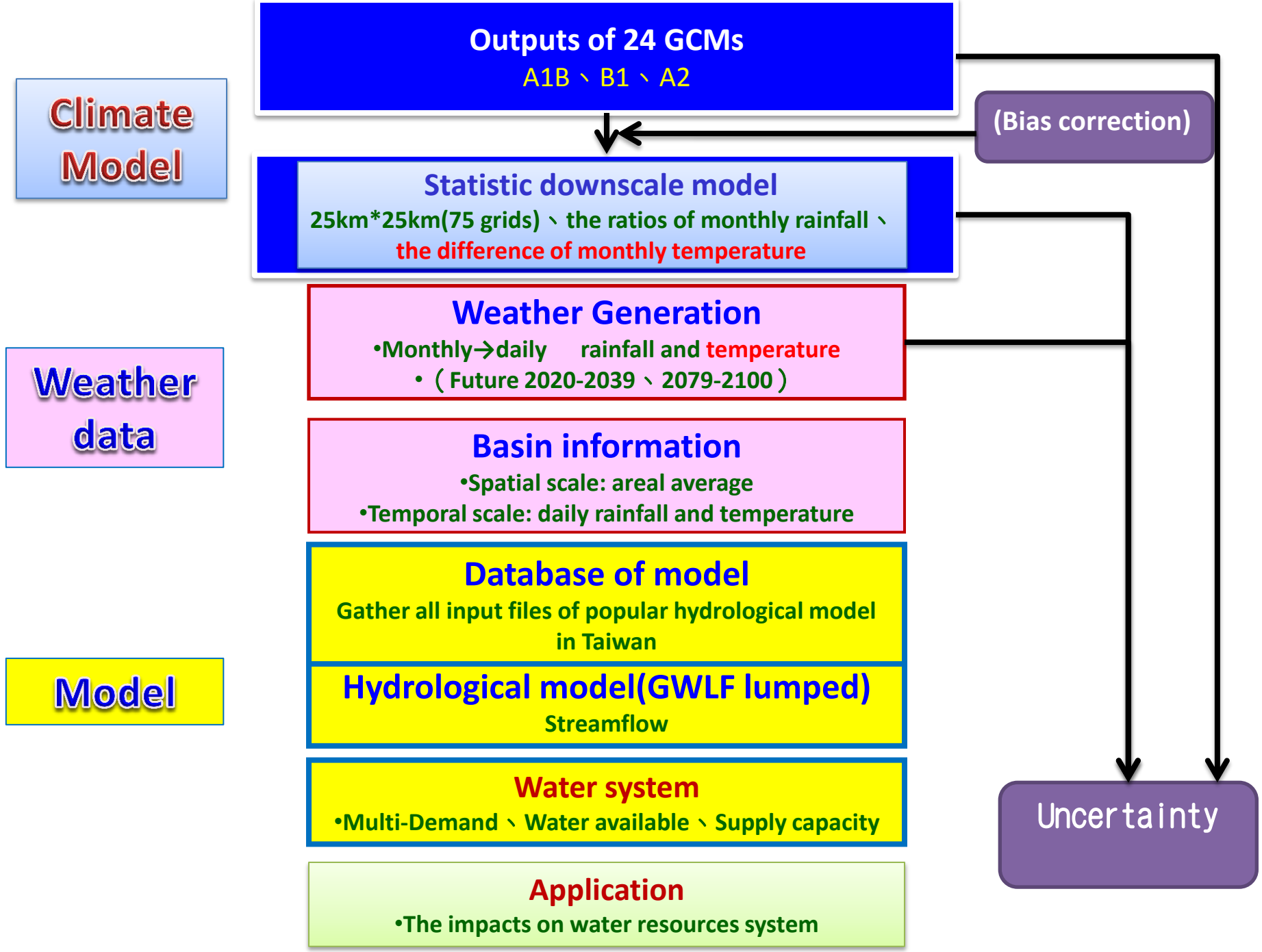
- **Not only the rainfall amount (during the extreme rainfall event), but also the rainfall pattern (temporal distribution) are crucial, especially under the climate change scenario.**
- **The GCM20 data will be downscaled by the local research team, the temporal distribution and its impact to the hydrology design will be examined.**

- **Part II Impact on water resources**

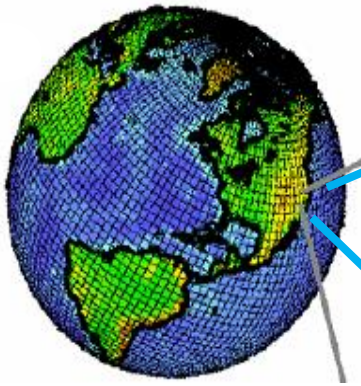
outline

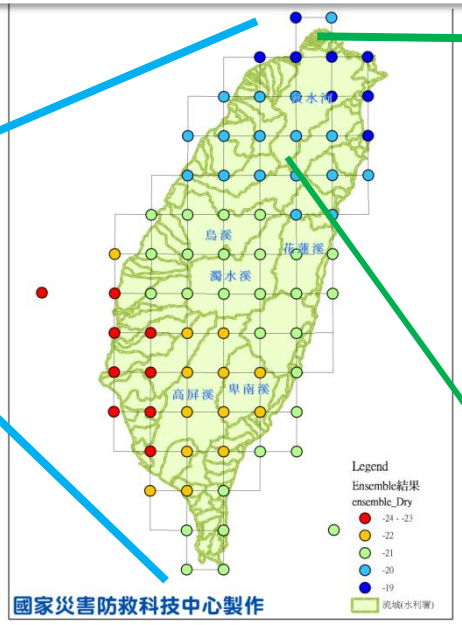
- **Assessment of the change rate of rainfall in dry and wet season in Taiwan**
- **Estimated impact of climate change on stream flow in Tansui River and Zengwun River**
- **Assess the uncertainty of GCM's and weather generation method**

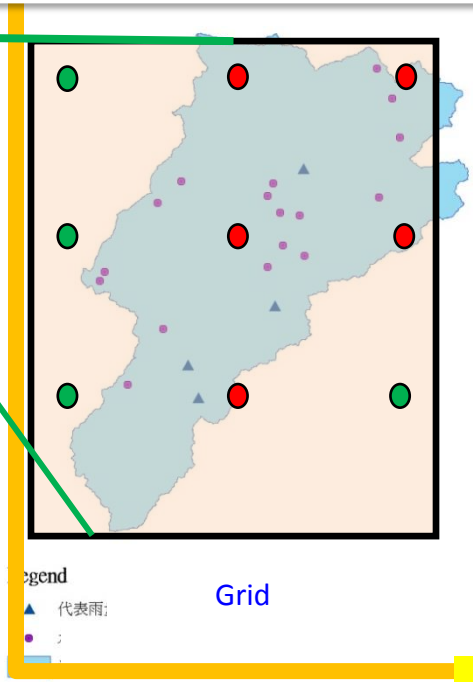
METHODOLOGY

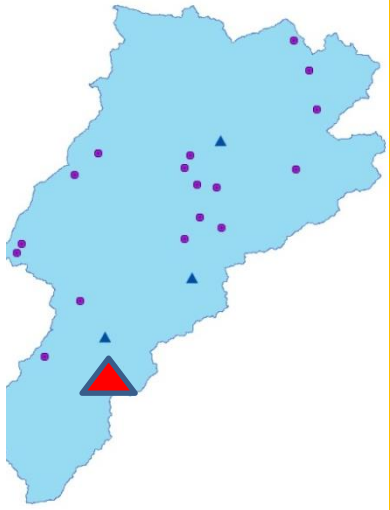

Climate Model
Outputs of 24 GCMs
A1B、B1、A2
(Bias correction)
Statistic downscale model
25km*25km(75 grids)、the ratios of monthly rainfall、
the difference of monthly temperature
Weather data
Weather Generation
•Monthly→daily rainfall and temperature
•（Future 2020-2039、2079-2100）
Basin information
•Spatial scale: areal average
•Temporal scale: daily rainfall and temperature
Model
Database of model
Gather all input files of popular hydrological model in Taiwan
Hydrological model(GWLF lumped)
Streamflow
Water system
•Multi-Demand、Water available、Supply capacity
Application
•The impacts on water resources system
Uncertainty

Applied the downscaling data to to weather generation in watershed





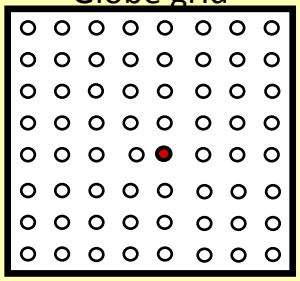




Grid

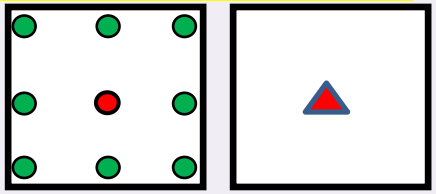
•Regional rainfall Station

Globe grid



GCM model
High resolution
weather output
From IPCC

Spatial Statistical Downscaling



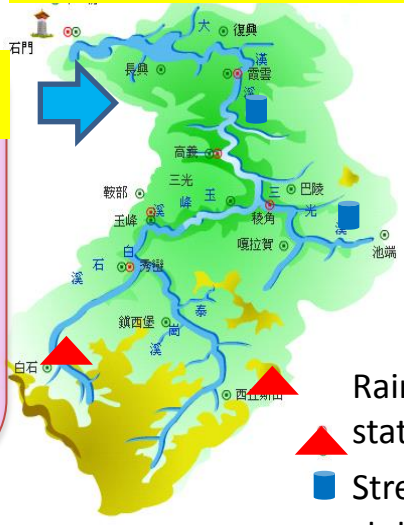
grid •Regional rainfall station

Change ratio of Monthly rainfall

weather generation

Monthly data→daily data
For input file of hydrology and water resource model

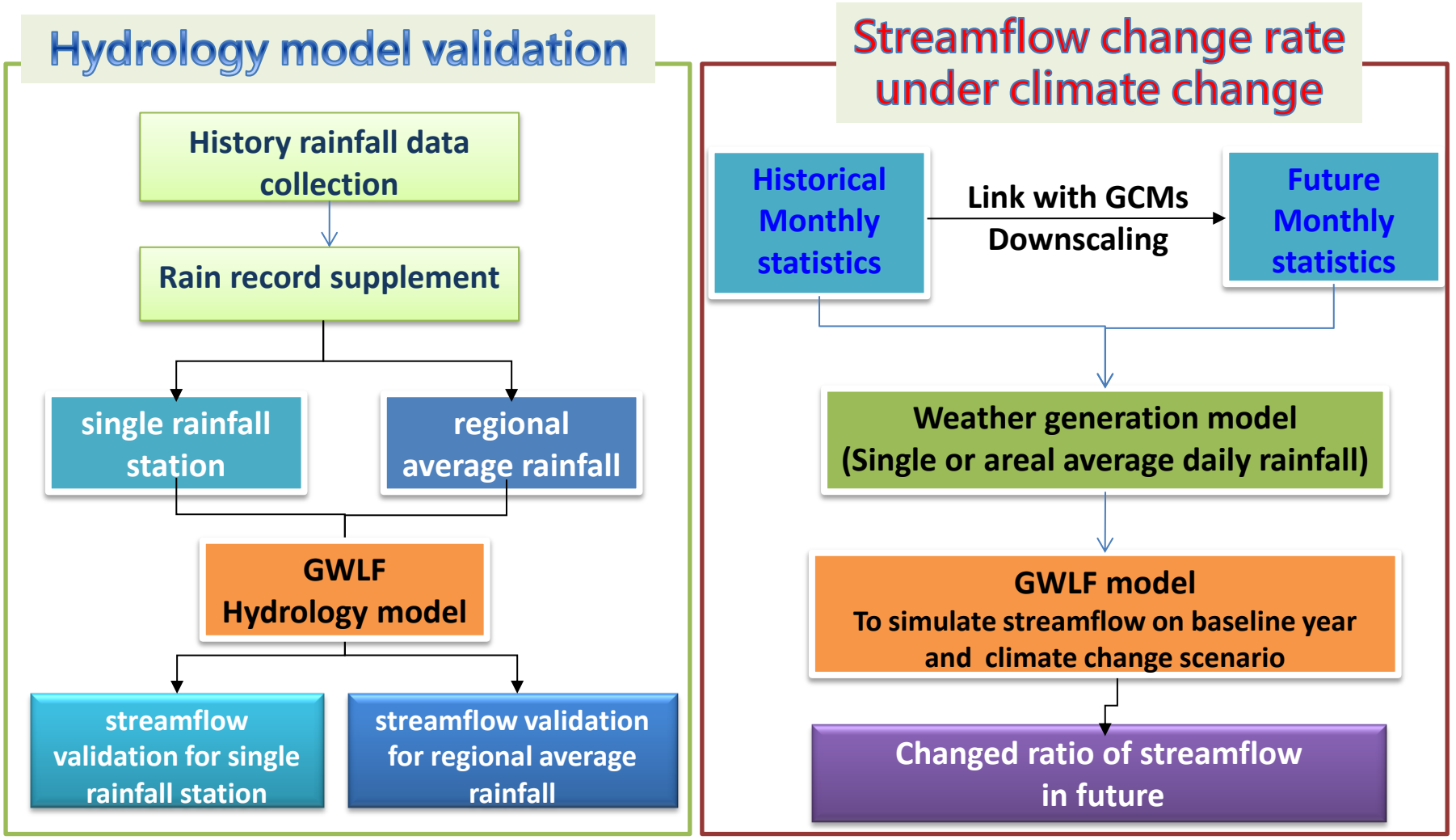
Hydrology simulation



Rainfal station

Stream station

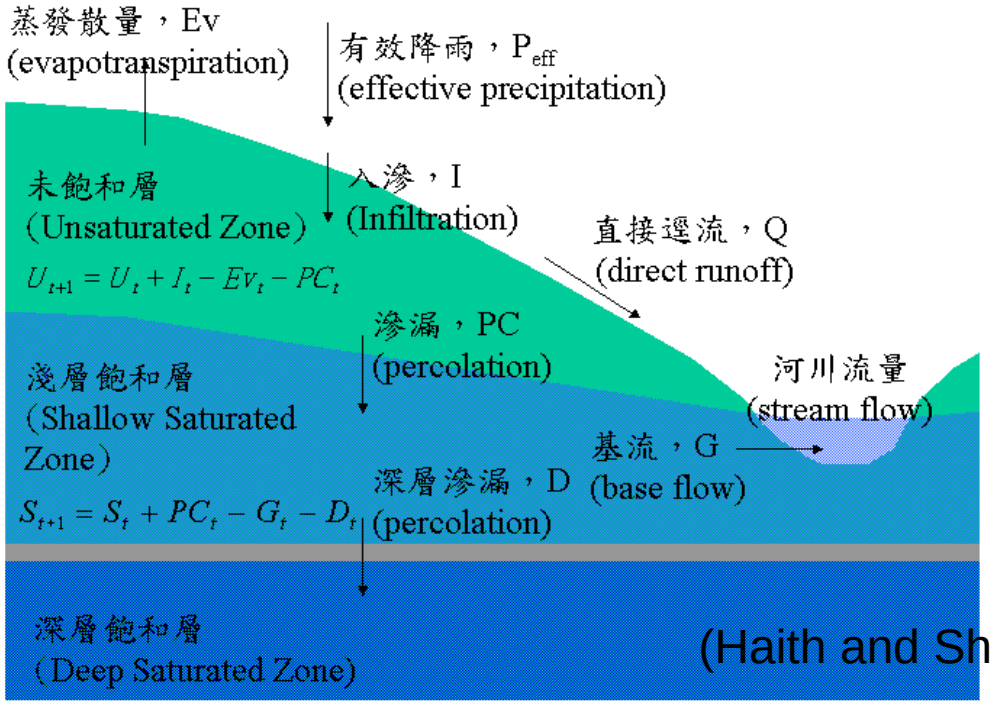
Process of streamflow analysis



Streamflow model(GWLF)

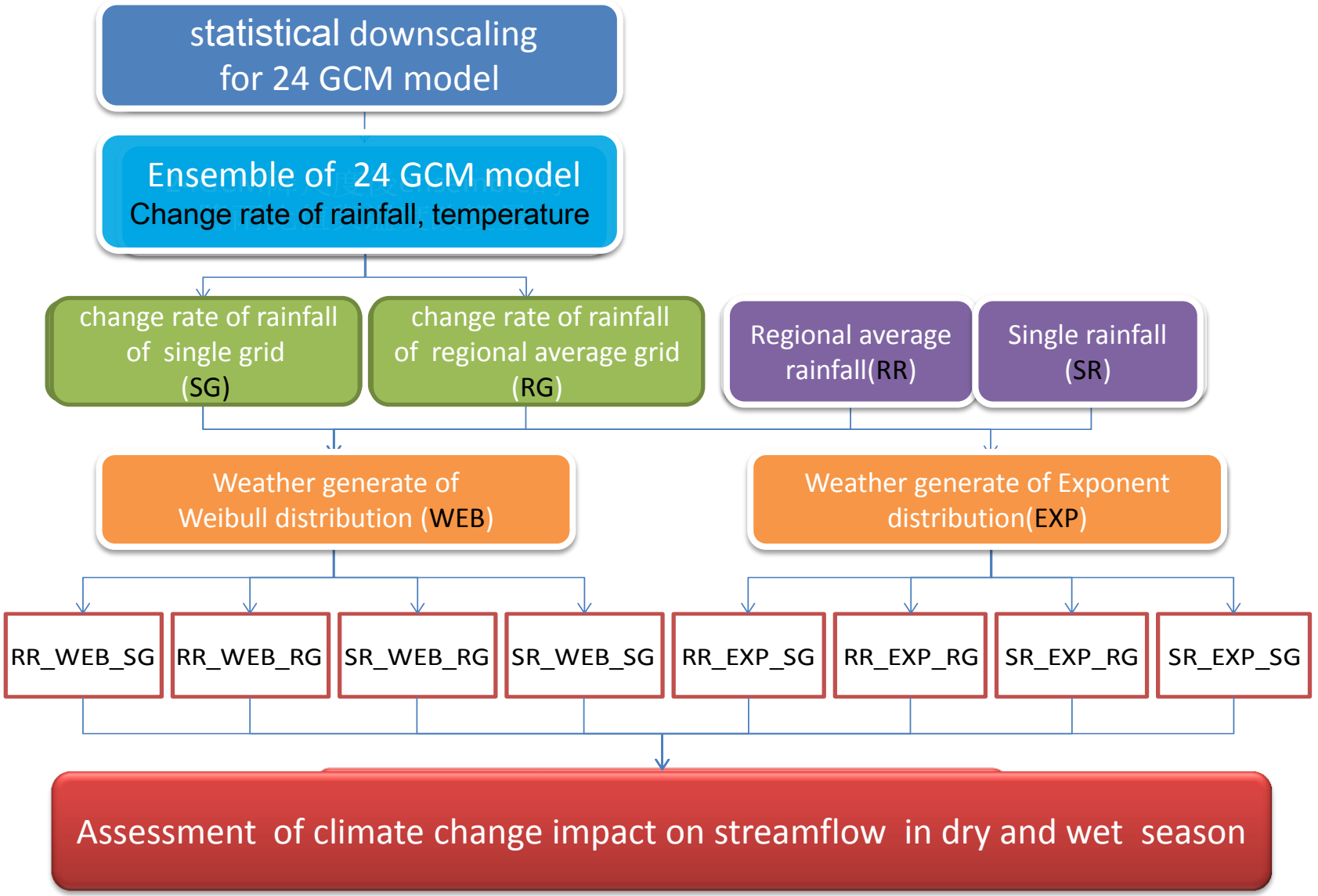
GWLF(Generalized Watershed Loading Functions)

- 1.A lumped model
- 2.Simulate in daily time step
- 3.Physical based model
- 4.Runoff estimated from SCS curve number



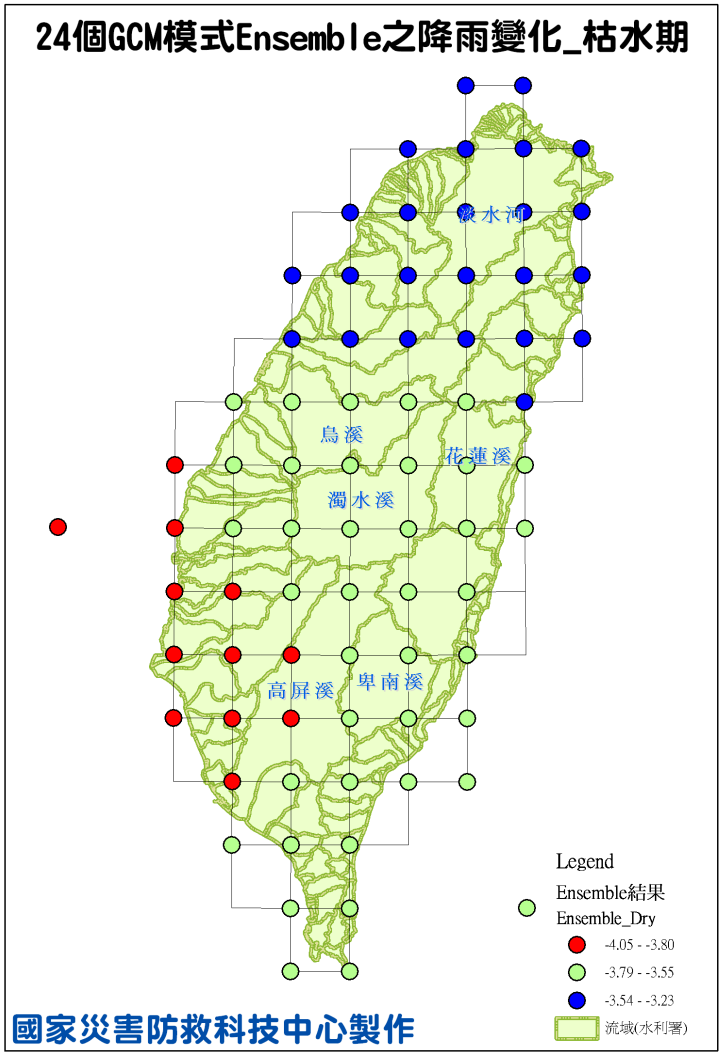
(Haith and Shoemaker, 1987)

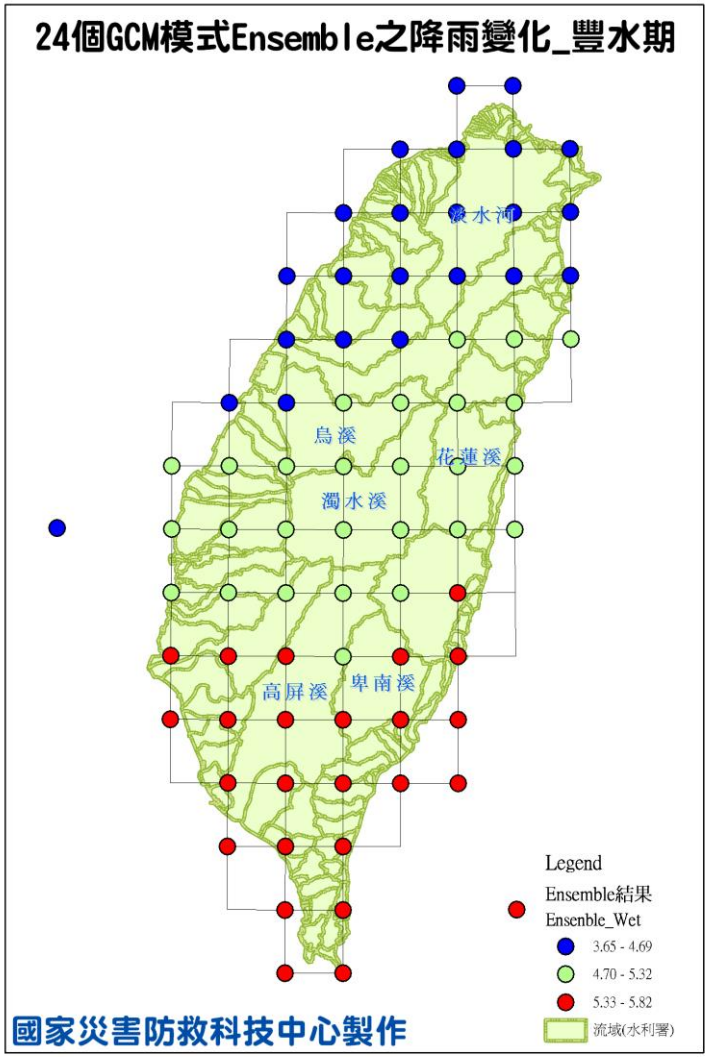
Uncertainty assessment for different weather generation



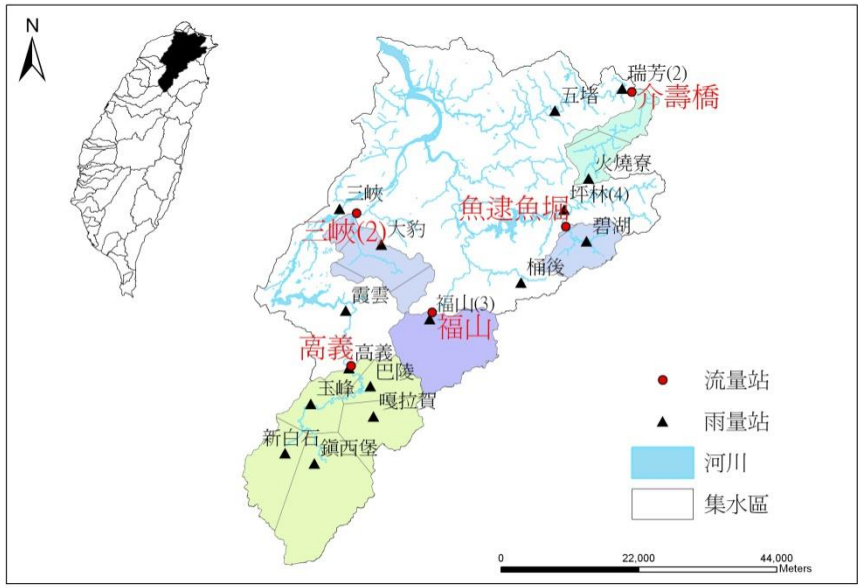
RESULTS

Change rate of Precip. in Wet and Dry spell

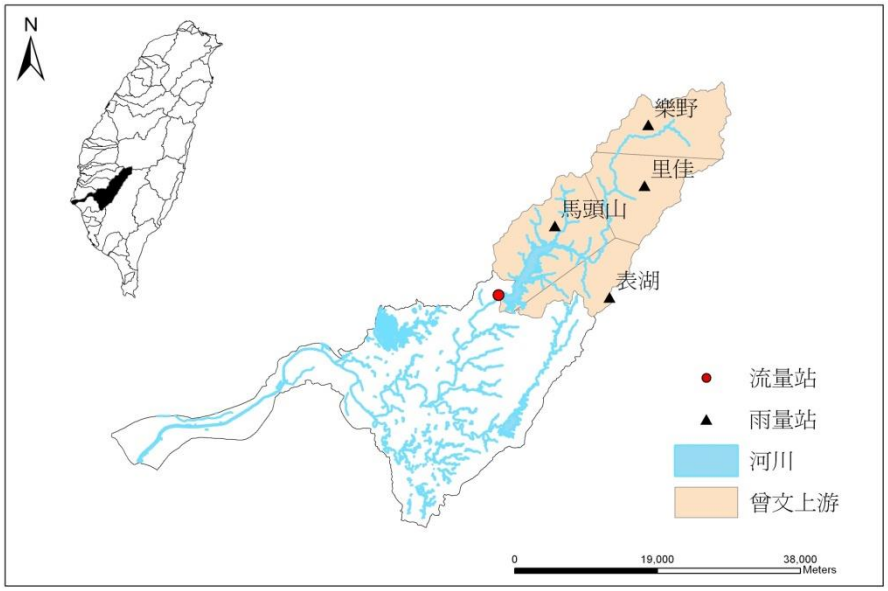




Study Area



DanShui River 淡水河



Tsengwen River曾文溪

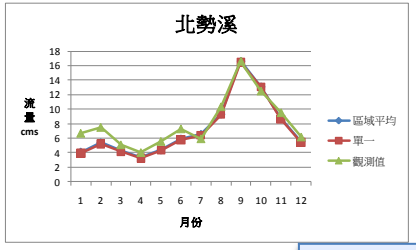
Validation of GWLF model

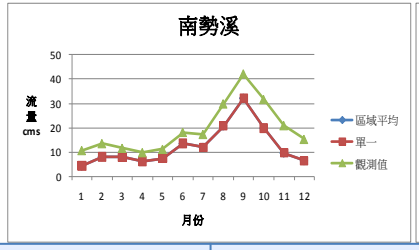
Single rainfall station streamflow validation

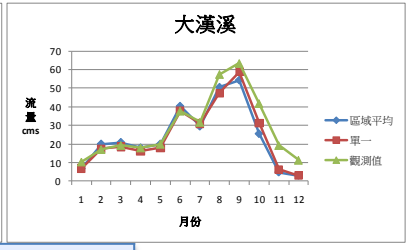
	NE (Nash-Sutcliffe efficiency coefficient)	R (Pearson moment correlation coefficient)	△ 總體積變化百分比
北勢溪	0.83	0.97	11.86
南勢溪	0.38	0.97	36.09
三峽河	0.86	0.96	16.02
大漢溪	0.86	0.94	0.22
基隆河	0.84	0.94	7.23
曾文溪	0.98	0.99	0.84

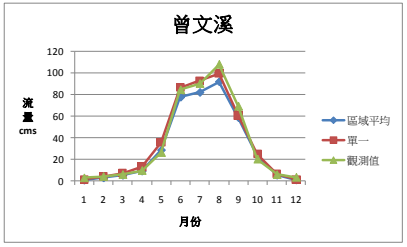
Area average rainfall Streamflow validation

	NE (Nash-Sutcliffe efficiency coefficient)	R (Pearson moment correlation coefficient)	△ 總體積變化百分比
北勢溪	0.85	0.97	10.33
三峽河	0.79	0.93	15.83
大漢溪	0.84	0.96	9.61
基隆河	0.83	0.97	12.64
曾文溪	0.97	1.00	9.96







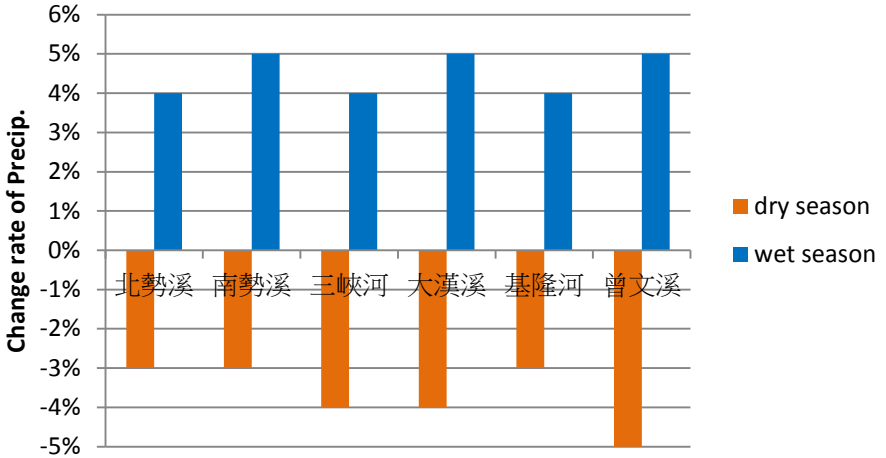


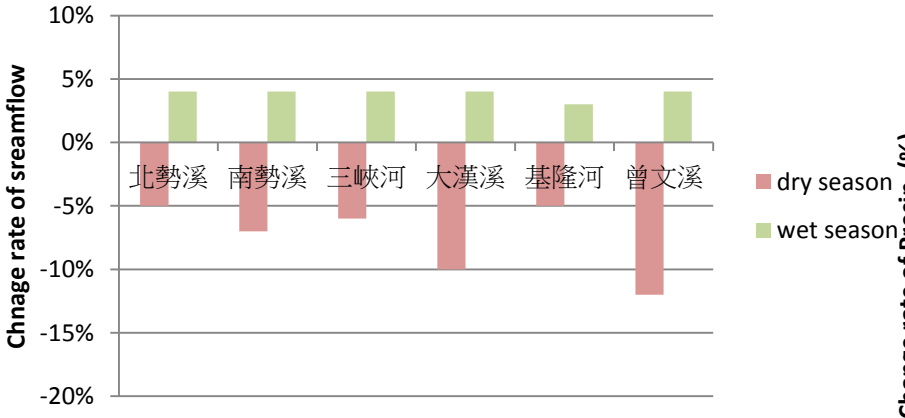
Annual rainfall	Annual streamflow
194917.6	217937.5

Change of rainfall and flow under climate change

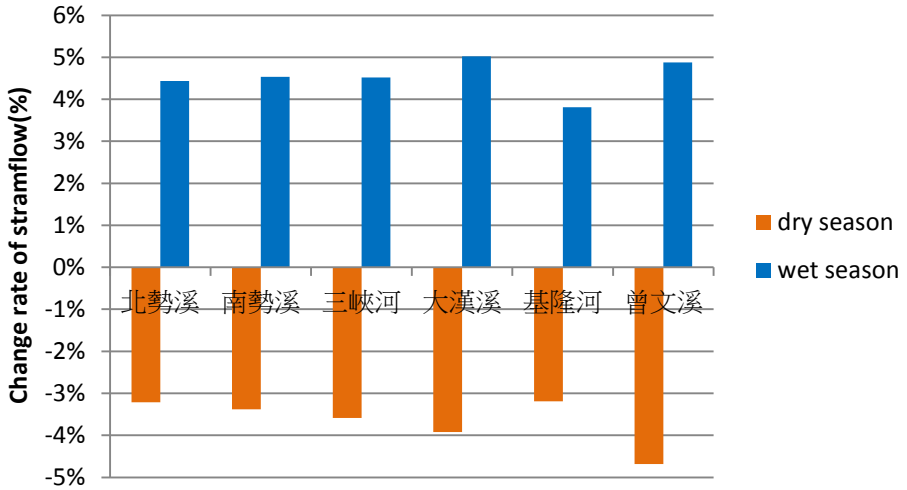
- 4% increase in wet spell，5%～10% decreasing in dry season

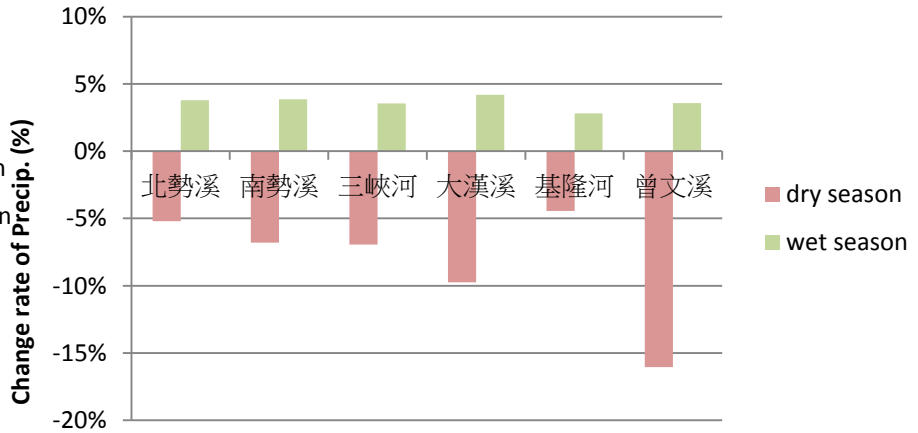
Single rainfall station





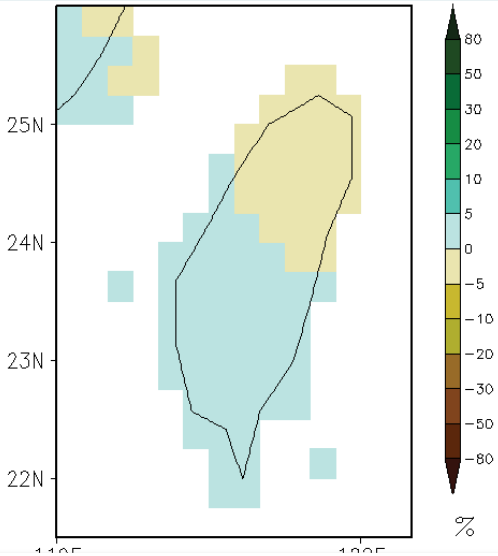
Area average rainfall



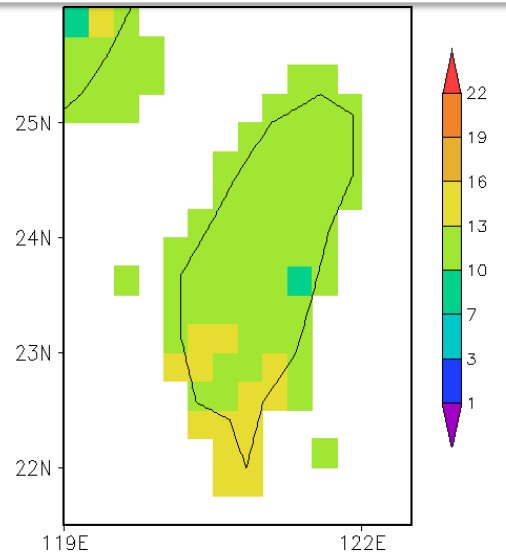


Uncertainty

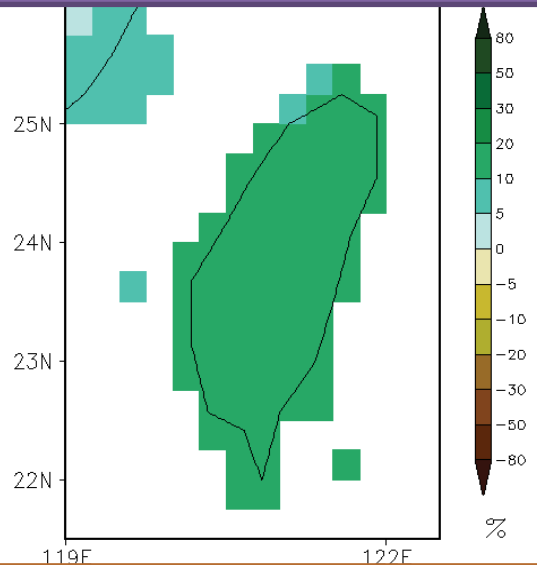
Change rate of Jan.



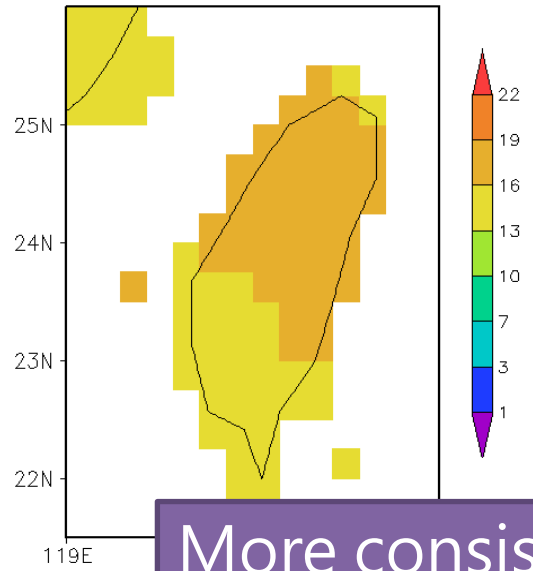
Number of model



Change rate of Jul.



Number of model

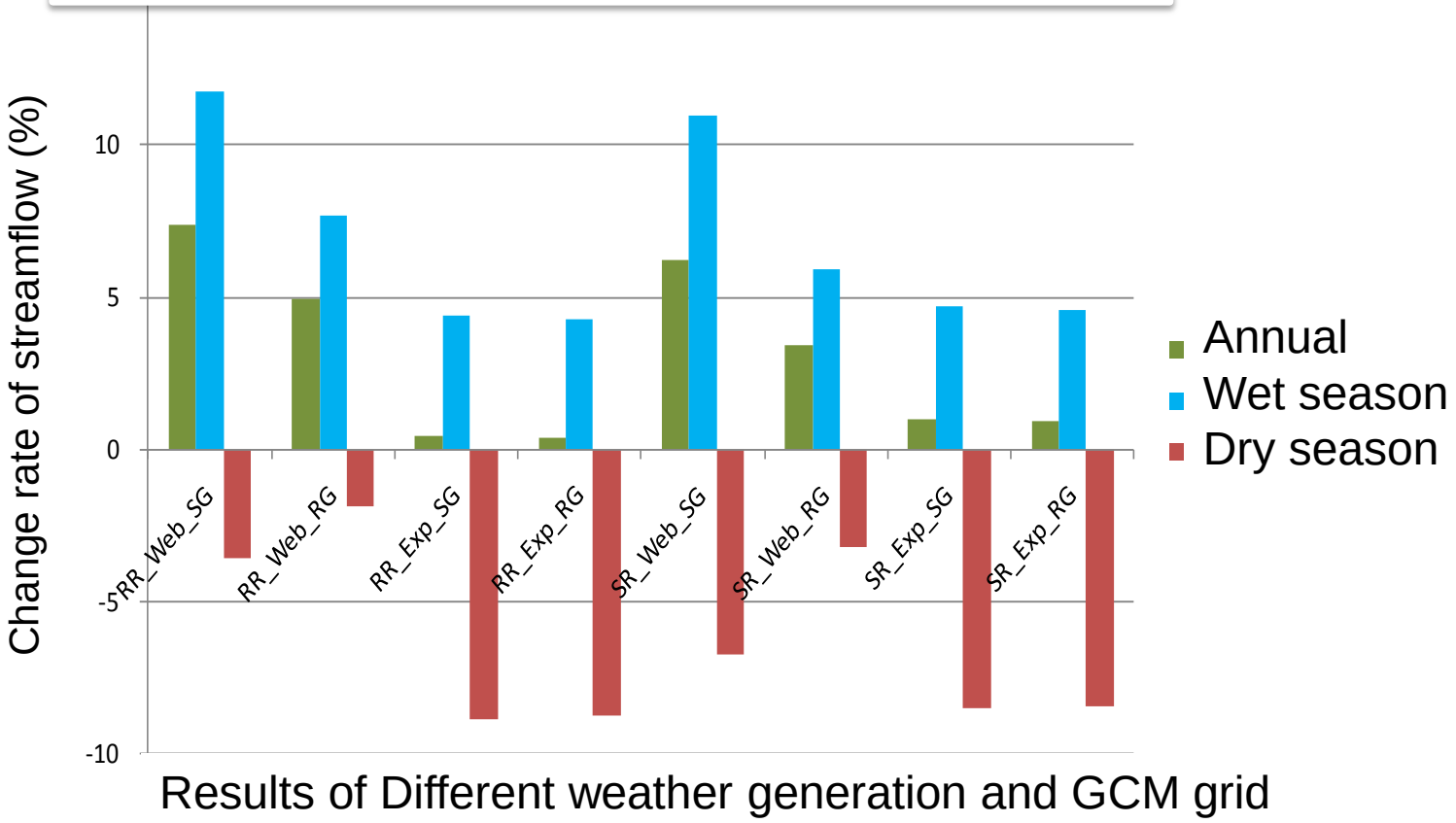


More consistent

(2020~2039) A1B

Changes of streamflow in different station, W.G., and Scenarios

Change rate is in between -10% ~ +10% during wet and dry season for Dan-Han river.



Conclusion

1. The results of precipitation in July are shown more consistent among all months.
2. After downscaling, the change ratio of precipitation in the southern Taiwan are more than that in other regions of Taiwan. It makes more difficult to adapt to climate change because the more increase in wet season and the more decrease in dry season.
3. The effects of climate change in streamflow are an increase of streamflow in wet season and a decrease in dry season. The change ratio is about ±10%.

Future work

1. Combine water resource systems to assess the effects between supply and demand.
2. The results with different uncertainty will be point with different adaptation.
3. In future, the uncertainty of the 24 GCMs are suggested to evaluated for quantifying the reliability of rainfall and streamflow .