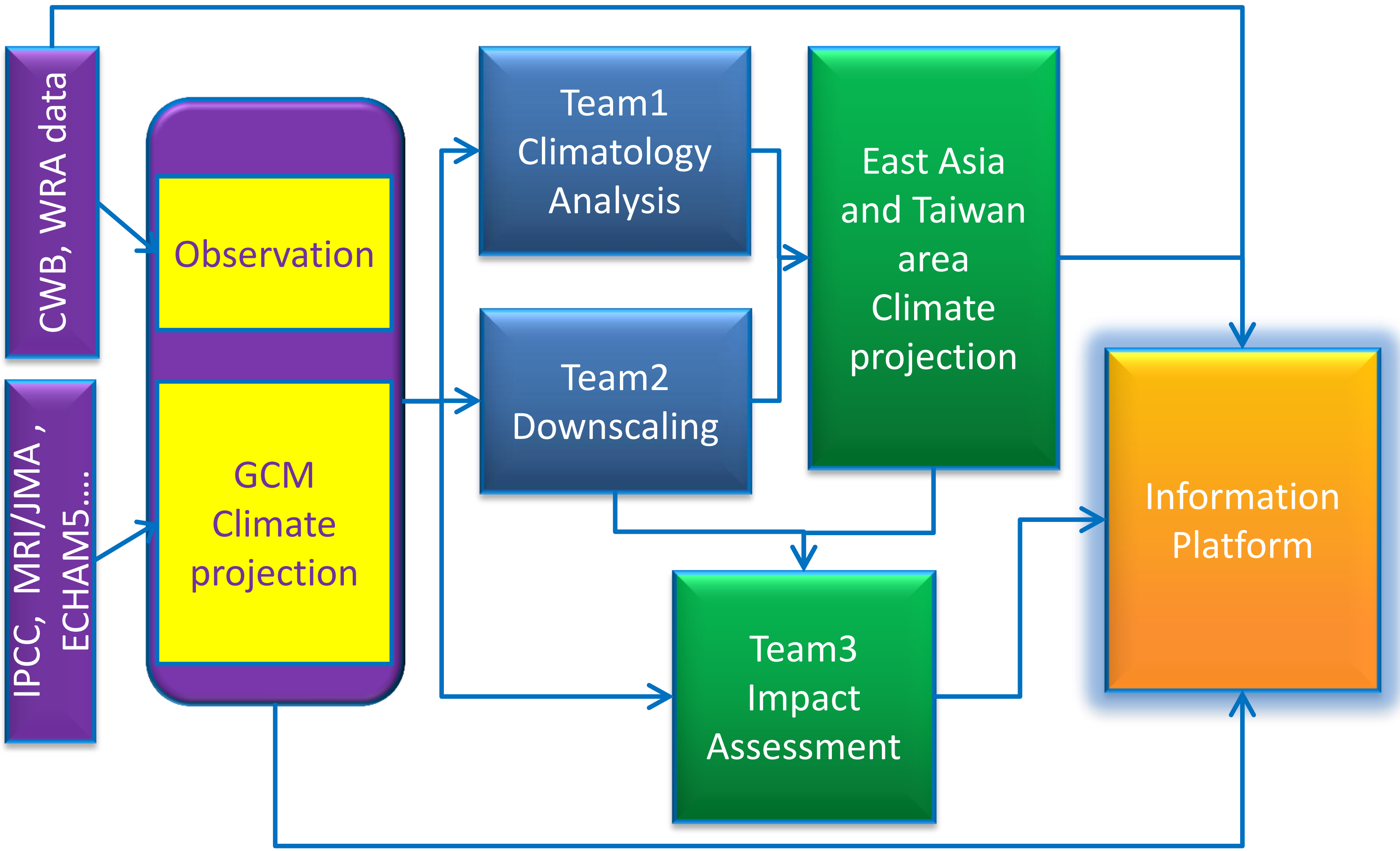
Taiwan Climate Change Projection and Information Platform Project

Uncertainty of Climate Change – – Case studies on Impact Assessment

Shen Chiang, Hsiao-Ping Wei, Yun-Ju Chen, Jun-Jih Liou
National Science and Technology Center for Disaster Reduction

2011 International Conference on Climate Change
2011.12.06-08

Taiwan Climate Change and Information Platform (TCCIP) project



Funded by NSC, the project of Taiwan Climate Change and Information will provide climate projection as the scientific basis for the policy making of climate change adaptation and impact mitigation.

Outline

- Introduction
- Uncertainty of climate change assessment
- Case studies
  - Impact and uncertainty of climate change on hydrologic design of flood
  - Impact and uncertainty of climate change on water resources
- Results and discussion
- Conclusion

Introduction

- Two case studies for quantifying uncertainty of hydrological impact under climate change were demonstrated.

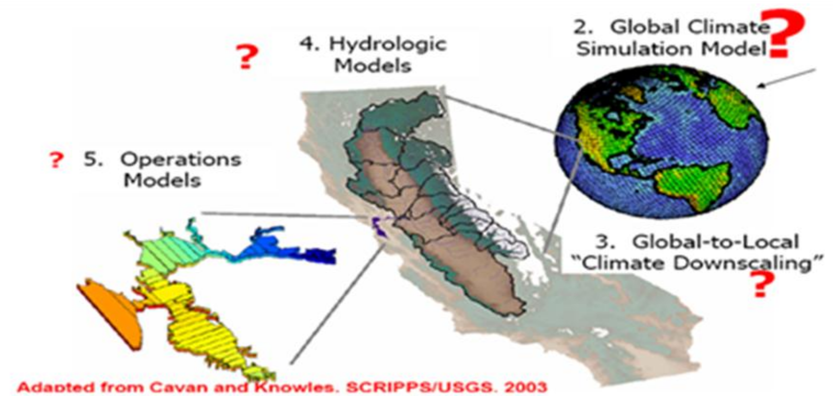
- First case study is focused on flood impact and natural variability with observed records and bias corrected MRI data. Bootstrap resampling method was used as uncertainty quantifying technique for natural variability.

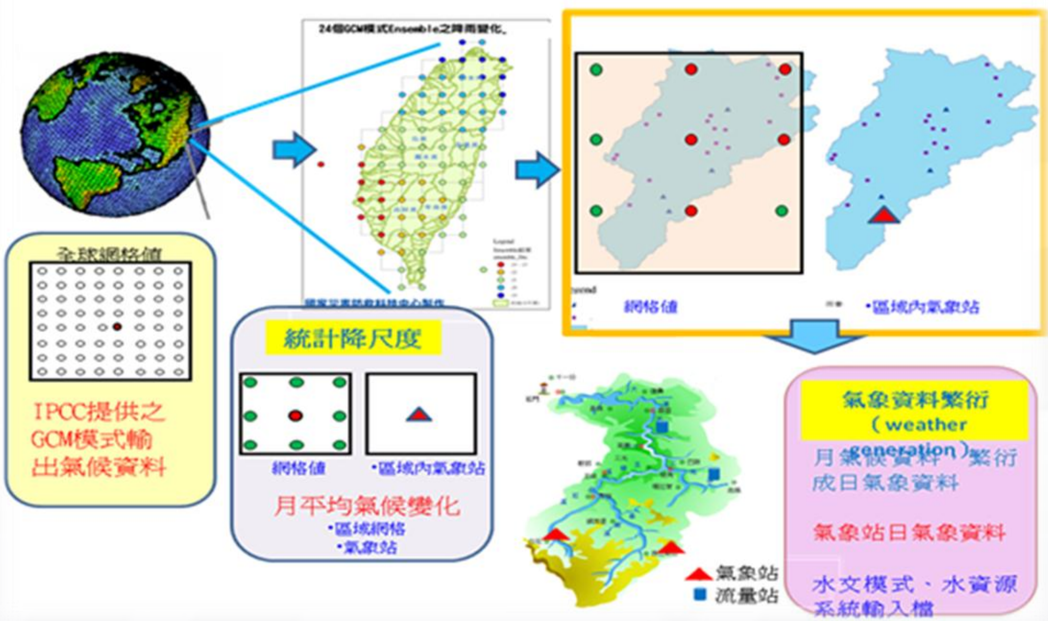
Introduction

- The second case study is exploring the uncertainty of water resource impact under climate change scenario. Studying uncertainty sources included GCMs, GHGs emission scenarios, WGs, projected period, and selected grids. Uncertainty of flow changed ratio was demonstrated by empirical cumulated distribution and confidence interval.

Sources of uncertainty

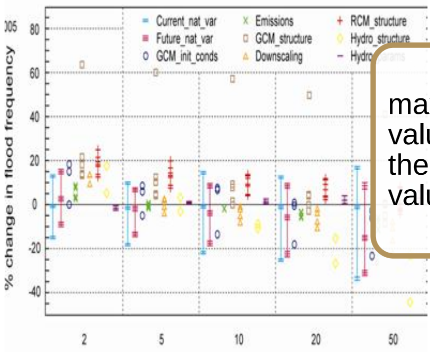
- General Circulation Models(GCM)
- Greenhouse gas emission scenarios
- Downscaling(Statistical、Dynamic)
- Hydrologic model
- Hydrologic parameter
- Operations models





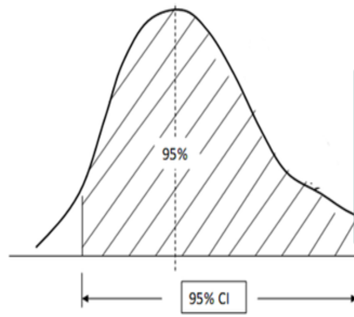
Uncertainty in the result display

Scatter Diagram



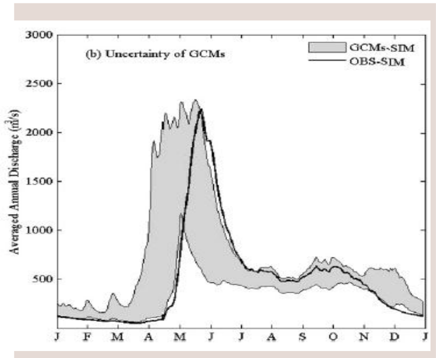
maximum value minus the minimum value

Confidence interval

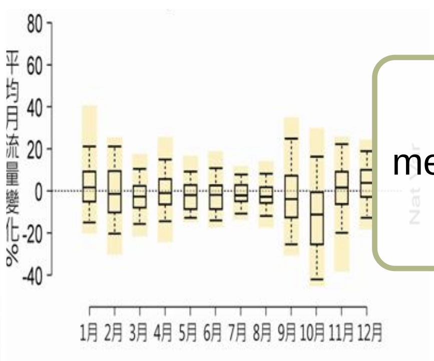


95% Confidence interval 、 Mean Value± Standard Deviation

Envelope

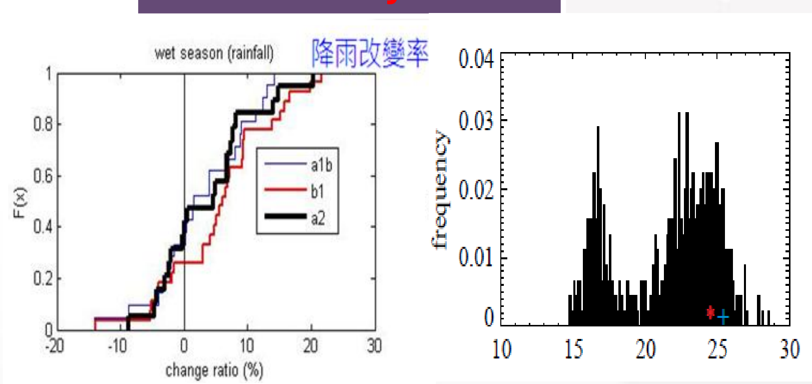


Box-and-whisker plot



median

Probability Plot



Probability Density Function, PDF 、 Cumulative Distribution Function CDF

Aim of this study

1. To assess influence and uncertainty of on hydrologic design due to climate change through analyzing the 1/100 maximum annual 24 hours rainfall from observation and Japan MRI data.
2. To estimate impacts and uncertainty of water resources due to climate change through simulating stream flow in wet and dry spell from statistical downscaling ,weather generator and hydrological model based on various GCMs and emission scenarios.

Impact of climate change

Flood

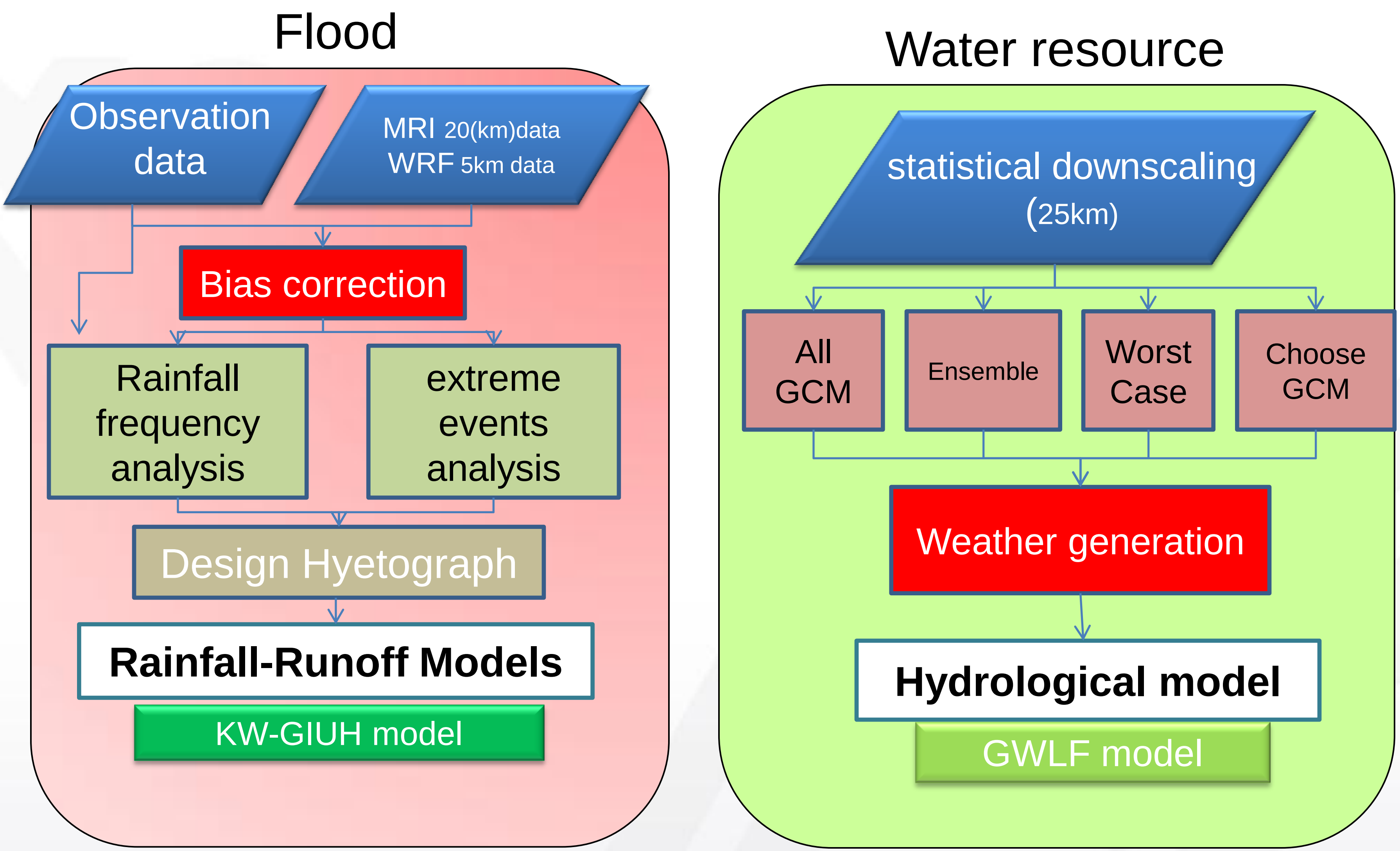
- Change of rainfall frequency
- Increased in the occurrence of extreme events
- Increased flood protection criteria

Water resource

- Frequency and Duration of drought
- Amount and timing of Inflows to reservoirs
- Reliability of water supplies
- Size and timing of flood control space

資料來源：水利署旱災服務網

Data and model

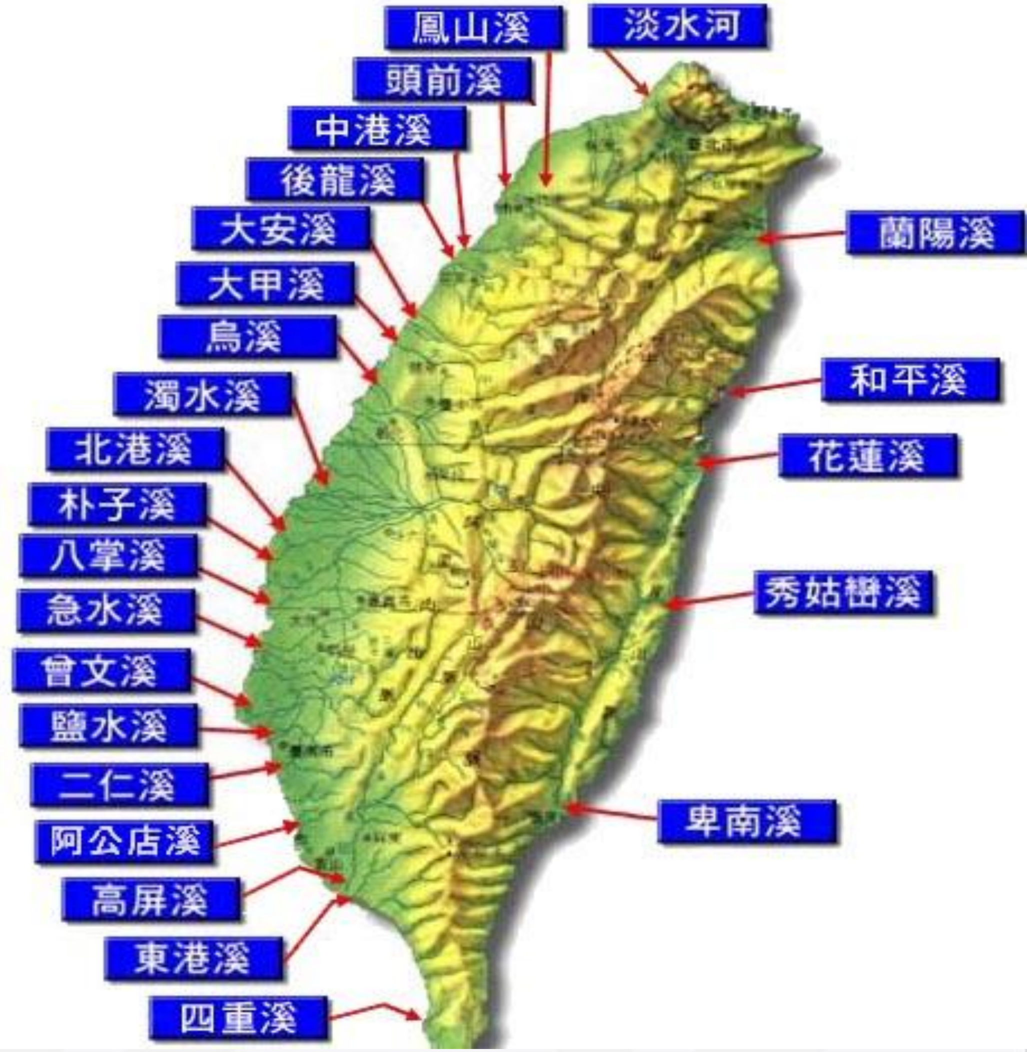


1. Impact and uncertainty of climate change on hydrologic design of flood

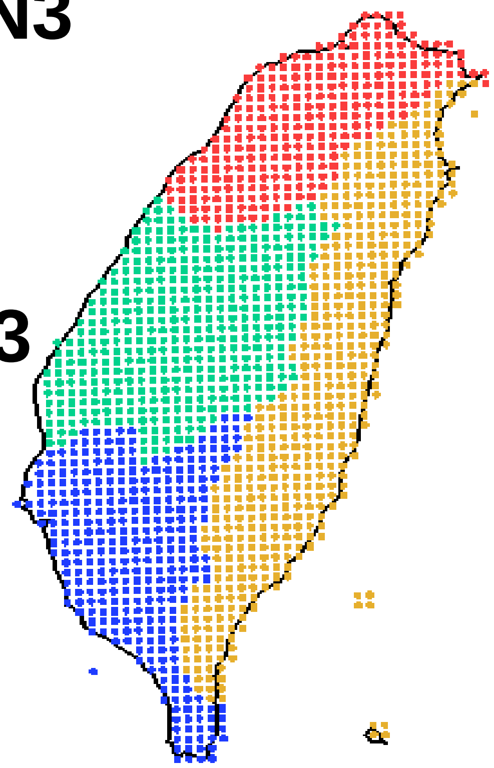
- Rainfall frequency analysis
- Flood Impact
- Data uncertainty

- **The approach of the study is begun with the analysis of the past rainfall observation, try to answer the question: Within limited future climate projection, what is the meaning of our impact analysis results?**

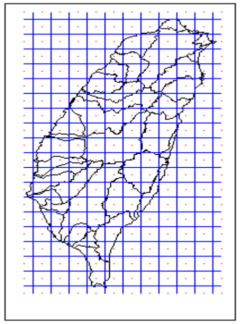
- The standard for Taiwan's flood preventing construction
  - Tanshui river basin (Metropolitan Taipei area): R.P.= 200 years
  - Central government in charge rivers: R.P.= 100 years
  - Local government in charge rivers: R.P.= 50 years
  - Urban drainage system: R.P.= 5 years



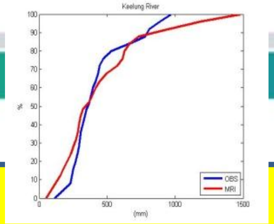
- **Recommended Empirical Distribution for Rainfall Frequency Analysis in Taiwan(proposed by WRA):**
  - **Northern Taiwan: PT3、LPT3、LN3**
  - **Central Taiwan: PT3、LPT3**
  - **Southern Taiwan: PT3、LPT3**
  - **Eastern Taiwan: PT3、LPT3、LN3**



Flowchart for assessing flood impact



MRI 20 km
WRF5km



Bias correction

Rainfall bias correction with gauge records

Hydrological frequency analysis under varied sample length

Bootstrap resampling

HFA and design flow analysis under different Bias Correction method

annual maximum series and annual exceedance series

Rainfall Frequency Analysis

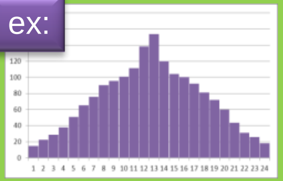
ex:

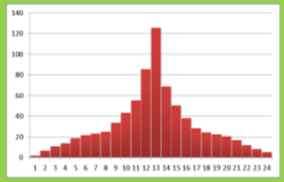
Rainfall Frequency Analysis 24hr；1/100		
PT3		
1979~2003	2015~2039	2075~2099
578.75	722.46	426.96

1/100 24hour Rainfall

Rainfall model

ex:





Rainfall-Runoff Model

KW-GIUH (Lee)

Flood Impact

ex

KW-GIUH catchment max discharge ratio		
1979~2003	2015~2039	2075~2099
1	1.32	0.68

Climate change impacts to hydrological design and uncertainty assessment

MRI Period Data

1979~2003 years	2015~2039 years	2075~2099 years

Bias Correction

Maximum rainfall in 24 hours (BC1)	Hours time-series data (BC2)

Rainfall Frequency Analysis

Pearson Type III

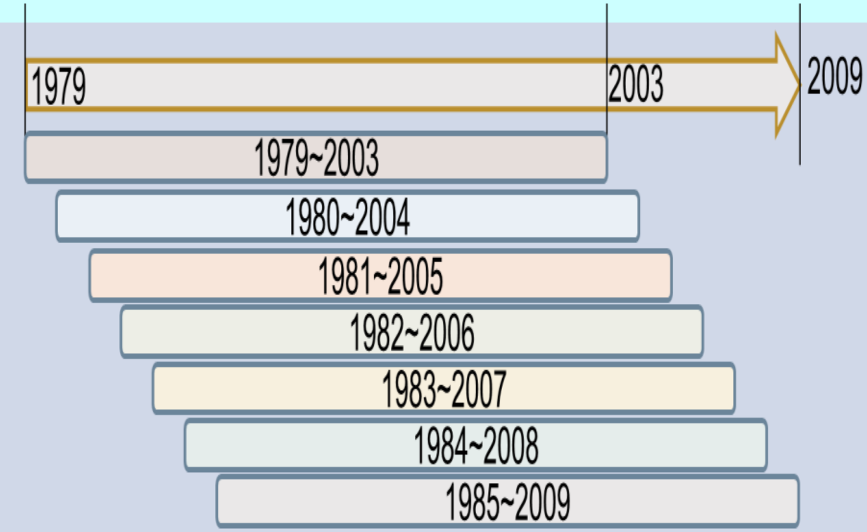
Flood Analysis

Kinematic-Wave Based Geomorphic Instantaneous Unit hydrograph (KW-GIUH)

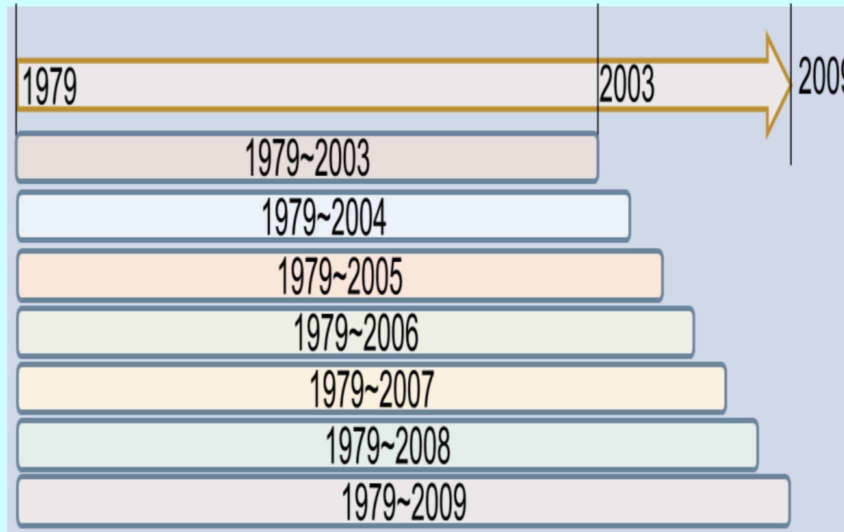
Natural Variability Uncertainty

Bootstrap technique

Different time period and scale



25-years sample length with varied periods

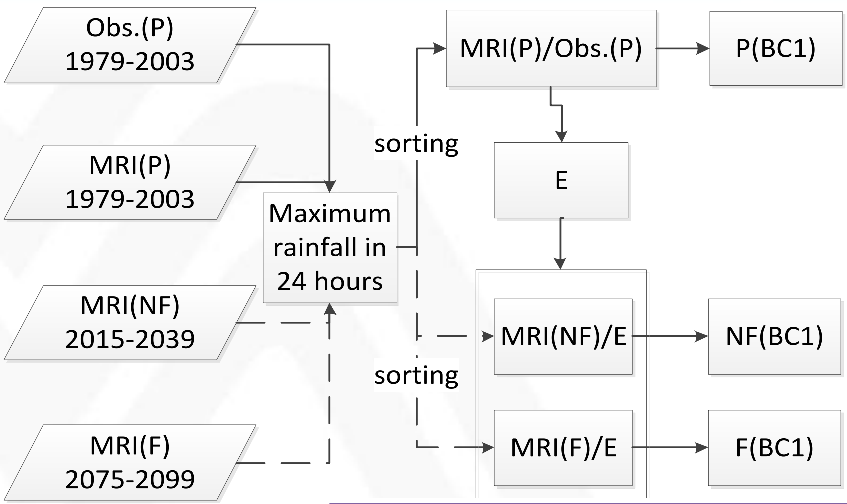


increasing sample length

By manipulating the AGCM data which provided by MRI for performing the impact analysis, we would like to know the possible influence which related to the data length (present, near future and end of the century, 25 years data length for each).

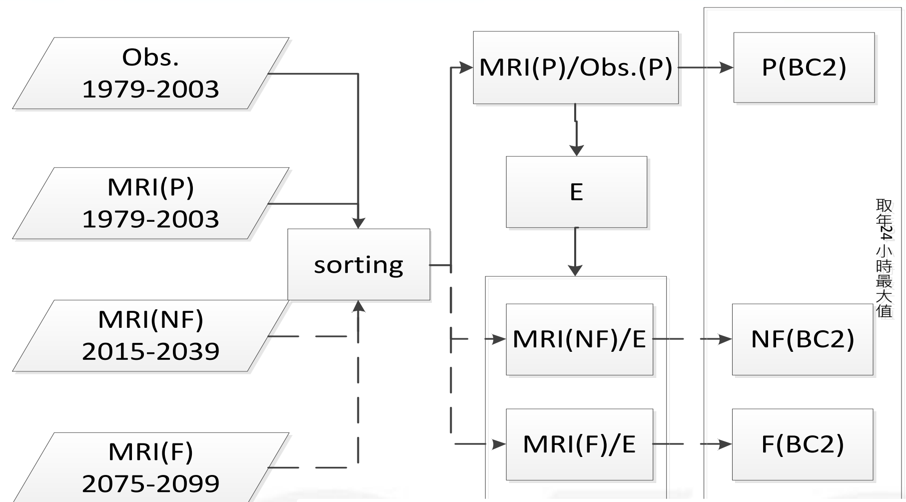
Two types of bias correction approaching

BC1



Biased correction with annual maximum rainfall series

BC2



Biased correction with hourly rainfall records

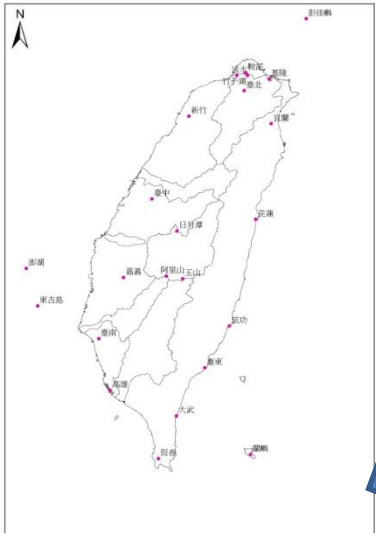
MRI(P) /Obs.(P) = E (for each percentile)

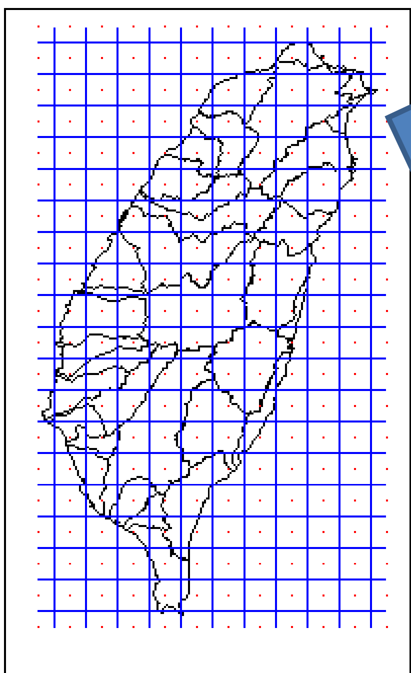
①MRI(NF) / E = NF

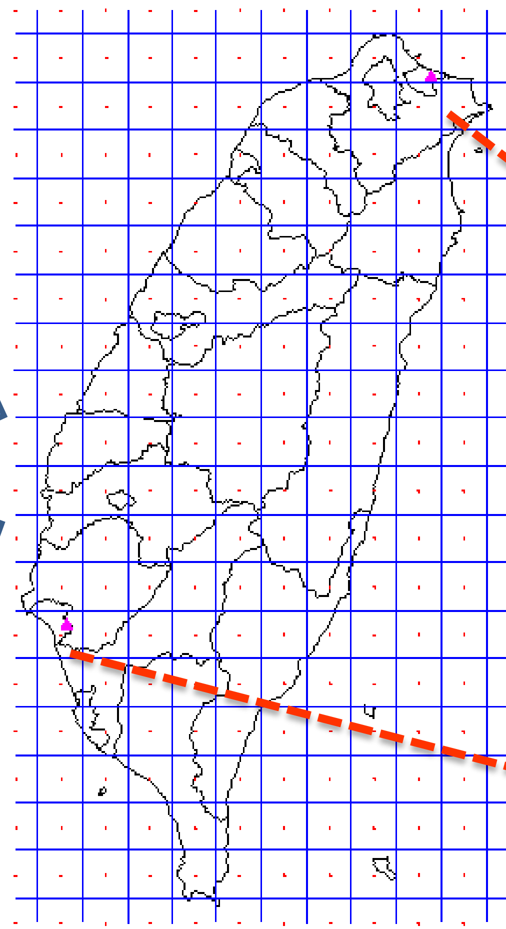
②MRI(F) / E = F

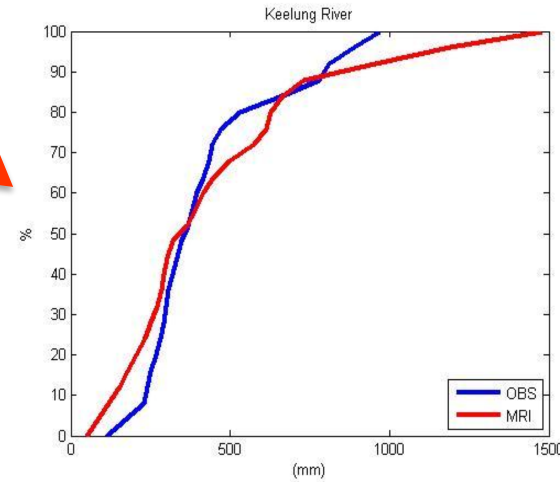
MRI(P): Present(1979~2003)
MRI(NF): Near future(2015-2039)
MRI(F): Far future (2075-2099)
Obs. (P) :Observation rainfall data
E:MRI present rainfall data(1979~2003)/ Observation rainfall data (1979~2003)
NF: Bias corrected MRI data in near future
F : Bias corrected MRI data in far future

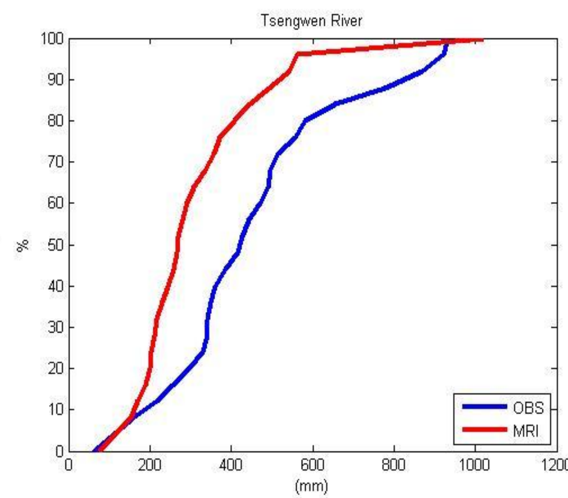
Bias correction with MRI data



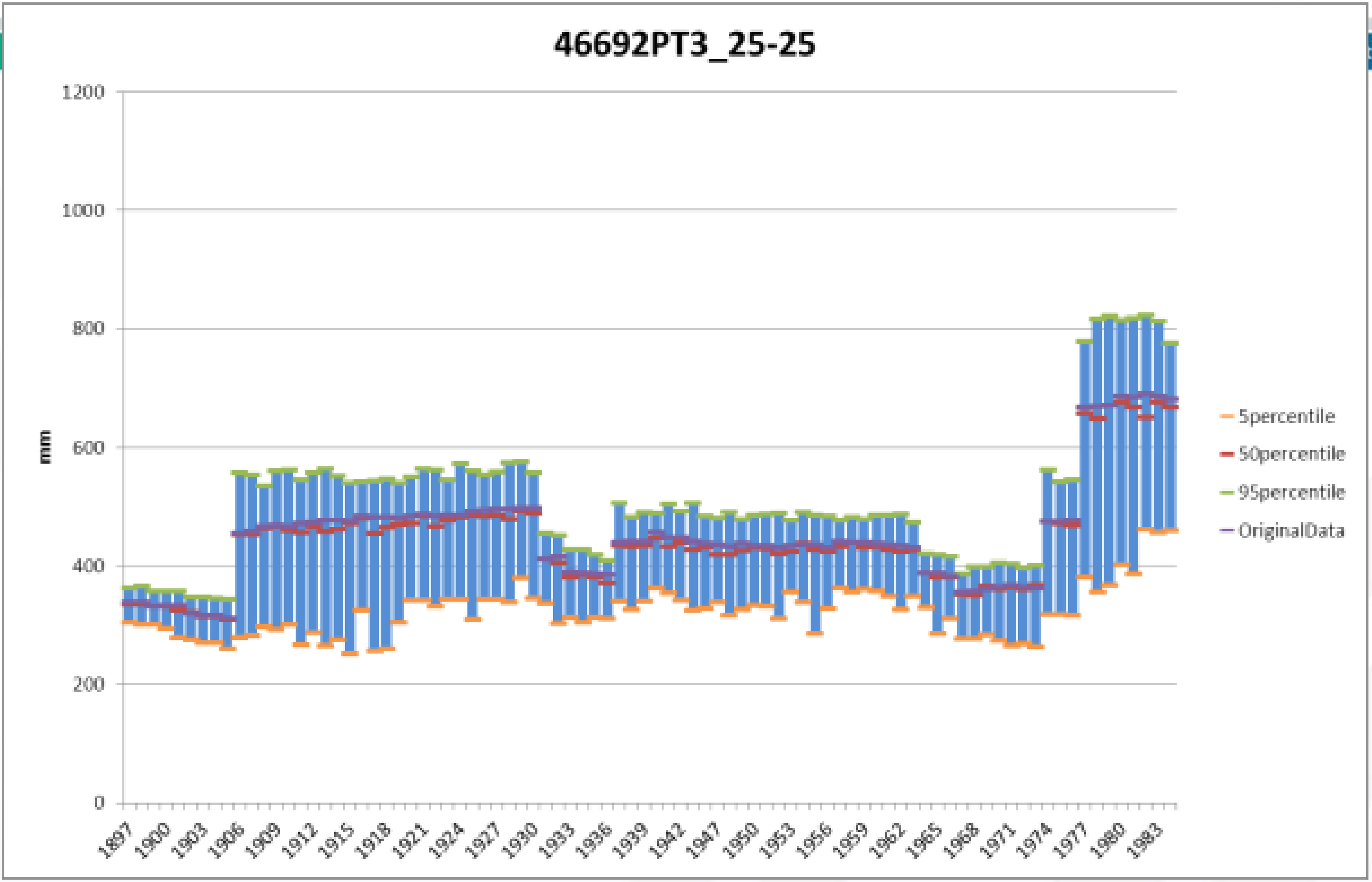






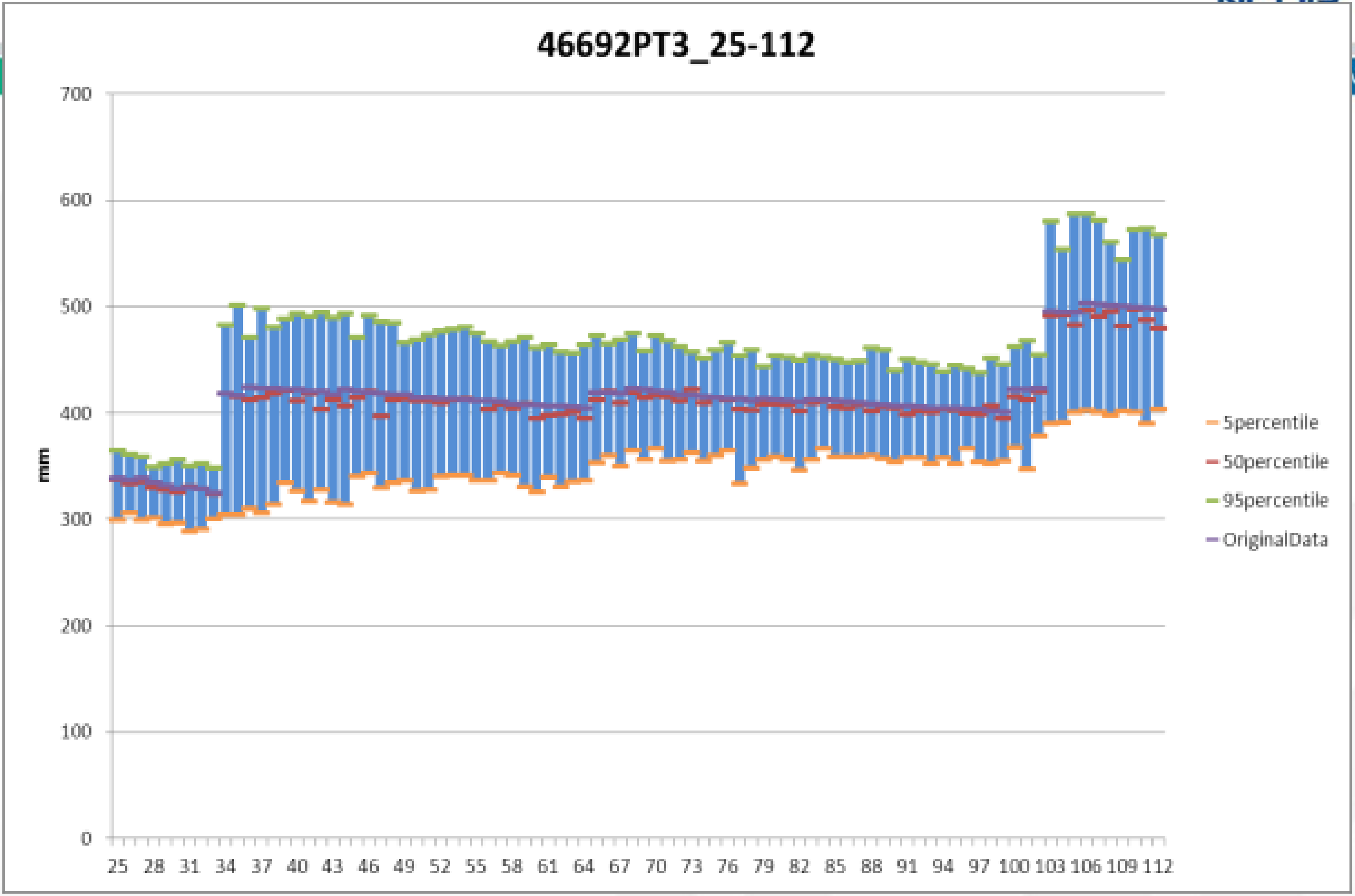


Natural variability of observation data



Data from 1897 to 2009, time window 25 years, shifted from 1897 to 1985

Natural variability of observation data

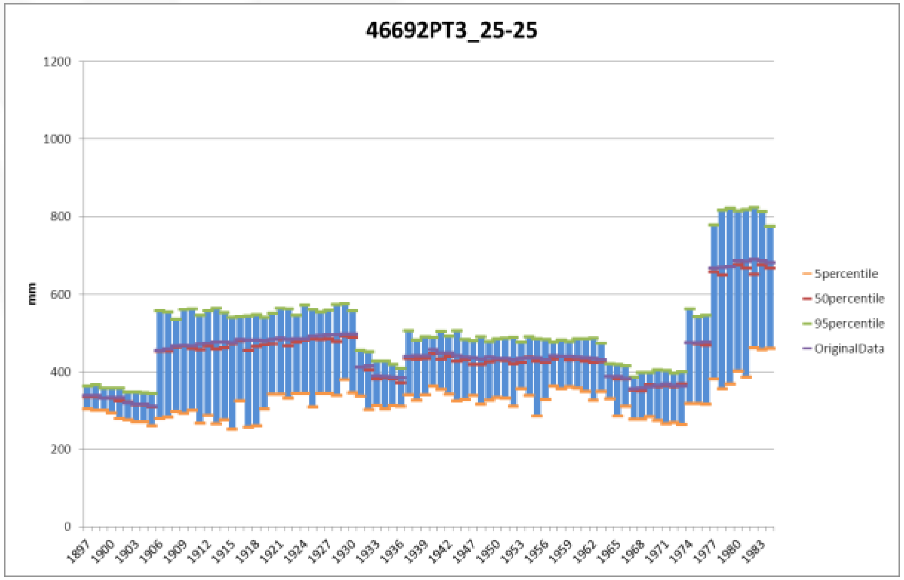


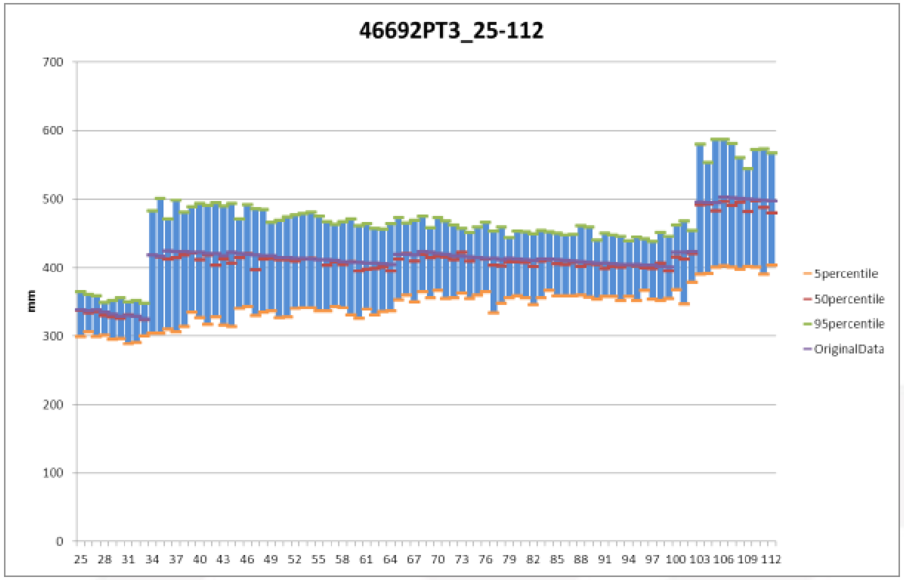
Data from 1897 to 2009, time window from 25 years to 113 years

Bootstrap resampling

www.ncdr.nat.gov.tw

- Both historical records and MRI data were separated into three periods(1979~2003, 2015~2039, and 2075~2099).
- 99 samples were resampled using Bootstrap method from each period data of historical records and MRI data.
- Percentiles (5%, 50%,and 95%) of both samples were compared to explore natural variability under observations and MRI data.

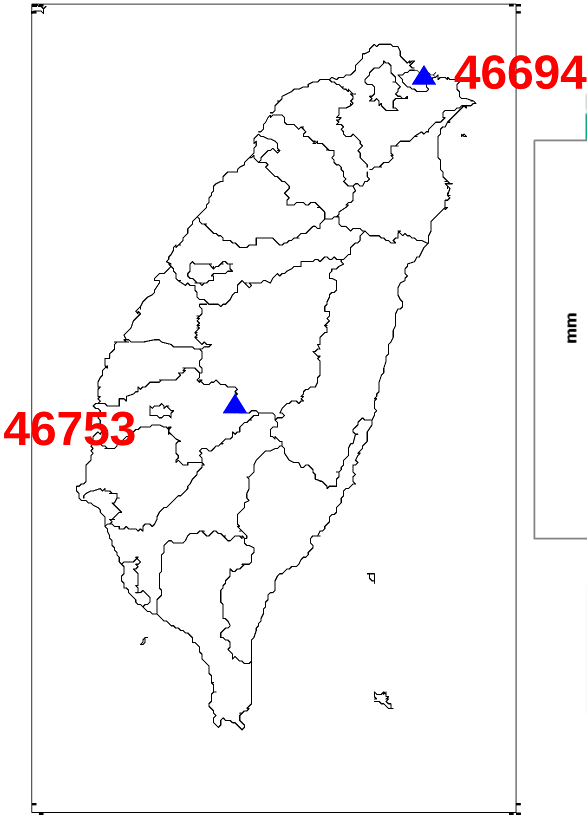

46692PT3_25-25
mm
5percentile
50percentile
95percentile
OriginalData

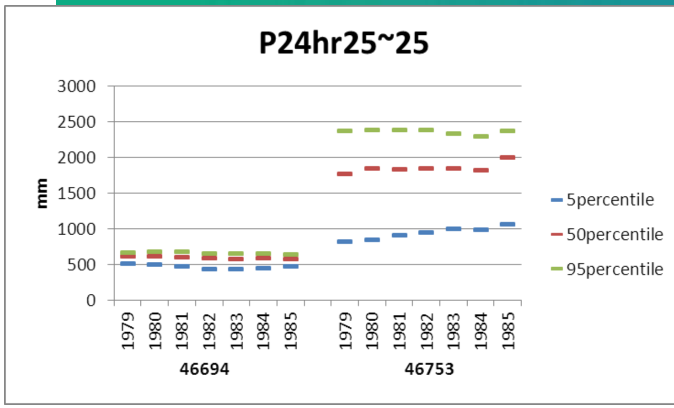

46692PT3_25-112
mm
5percentile
50percentile
95percentile
OriginalData

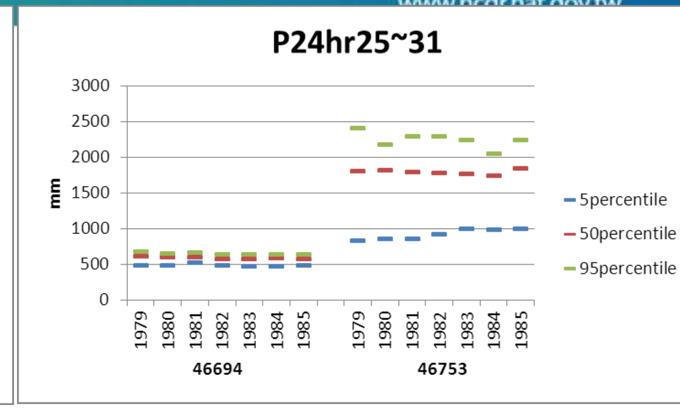
Natural variability using MRI and WRF data

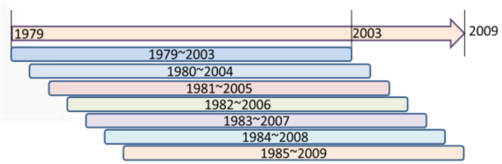
- Historical observations(sample length:25-25, 25-31)
  - obs x1 + bootstrap sample x 99=100
- MRI:
  - 25 yrs(three periods,1979-2003, 2015-2039, and 2075-2099)
  - 75 yrs(one period composed of 1979-2003, 2015-2039, and 2075-2099)
  - 121yrs(1979-2099)

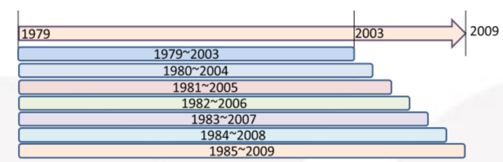
Historical observation data





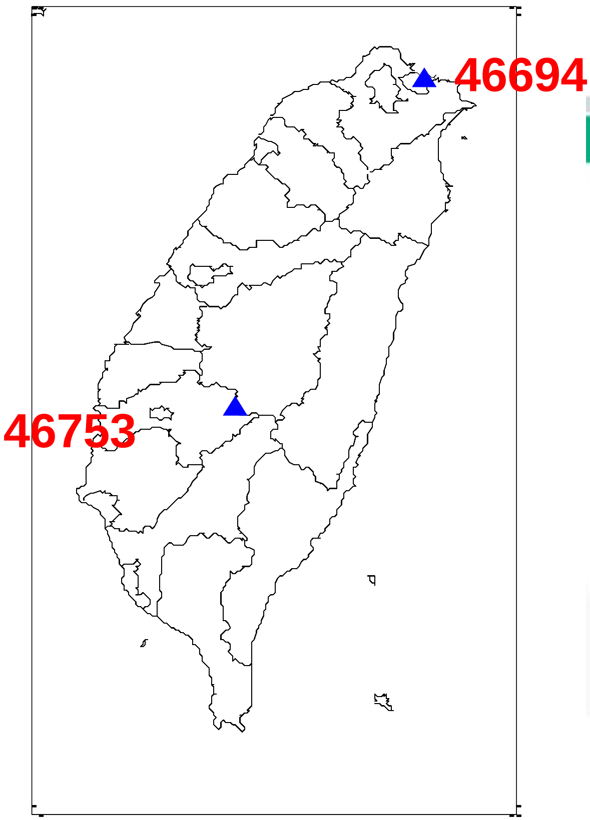






By using historical rainfall data (1979-2009), 2 kind of time window are applied for rainfall frequency analysis (1/100, 24 hours rainfall, PT3 distribution), also bootstrap resampling is applied for variability assessment.

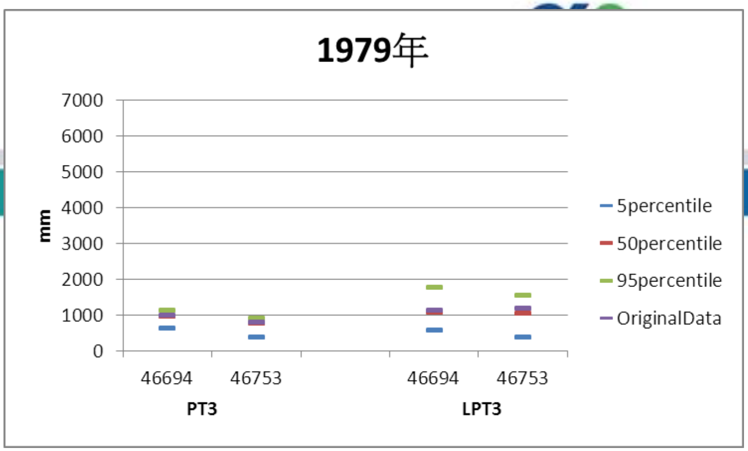
MRI data

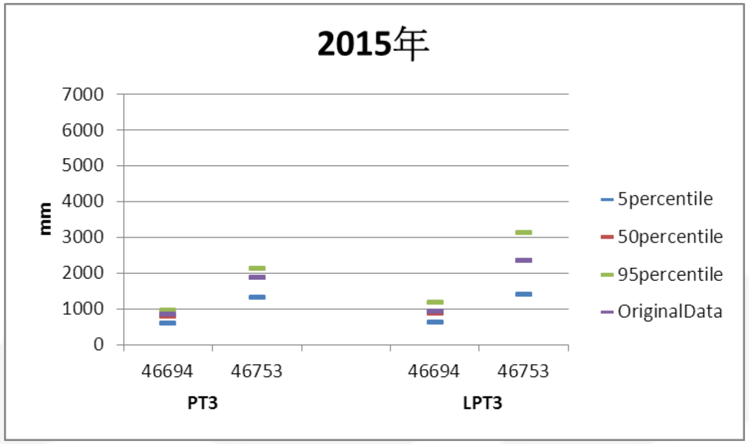


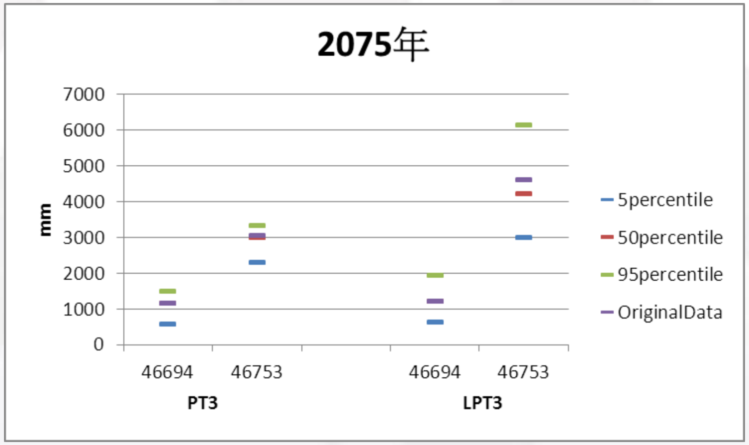
1979~2003
(25)

2015~2039
(25)

2075~2099
(25)

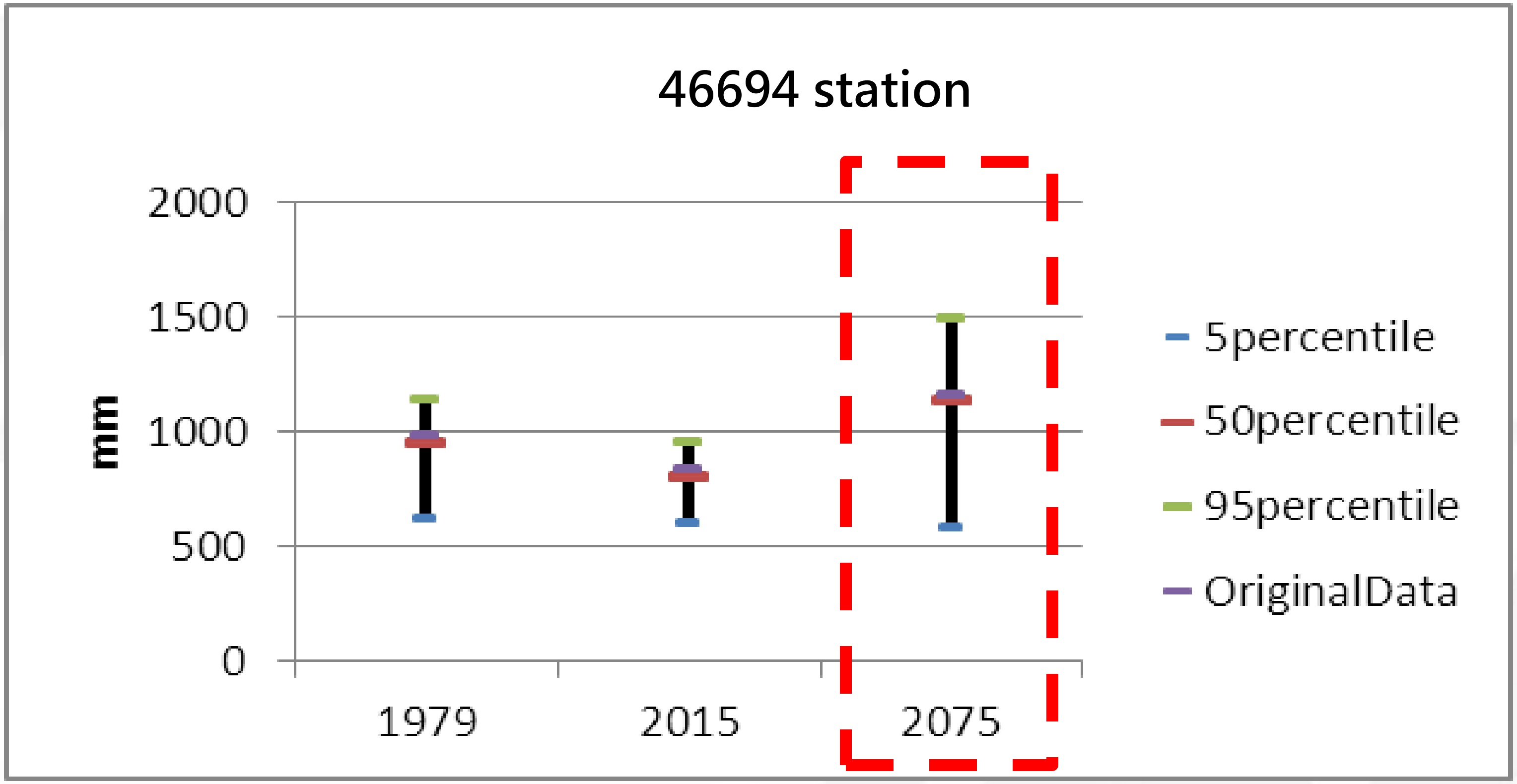






MRI data variability assessment (PT3)
2075-2099>2015-2039>1979-2003

MRI data variability

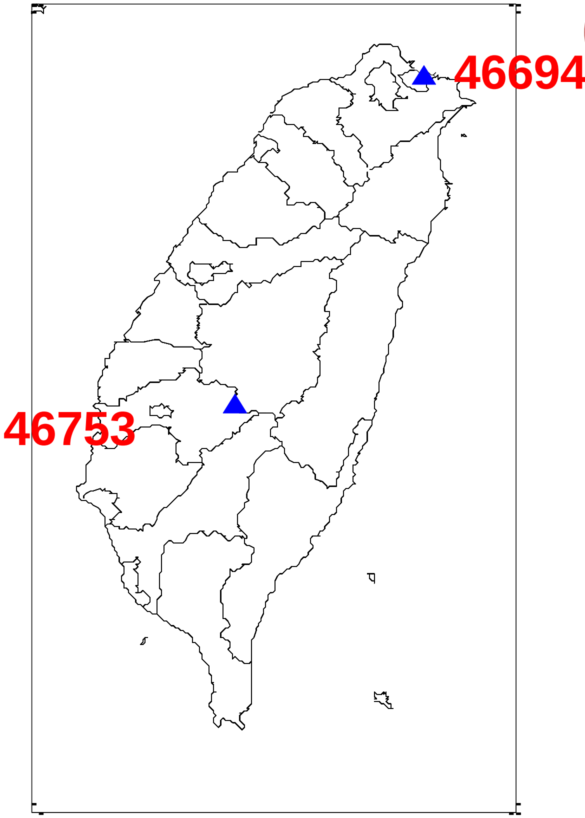


2075~2099 years

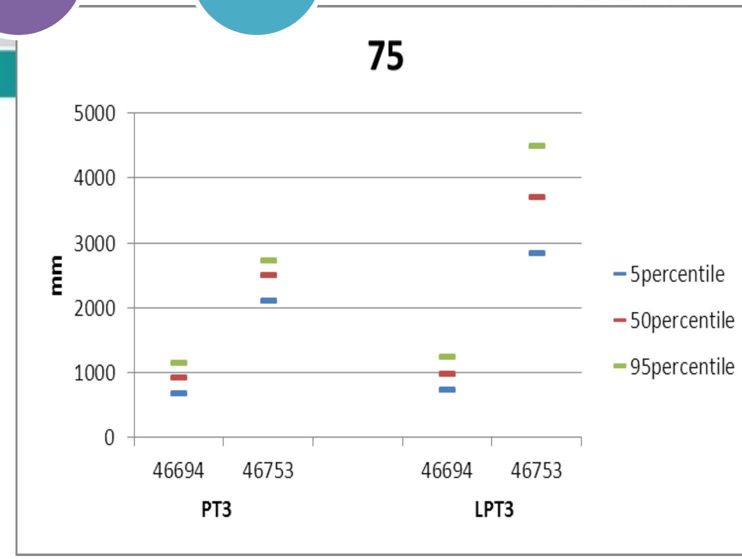
1979~2003 years

2015~2039years

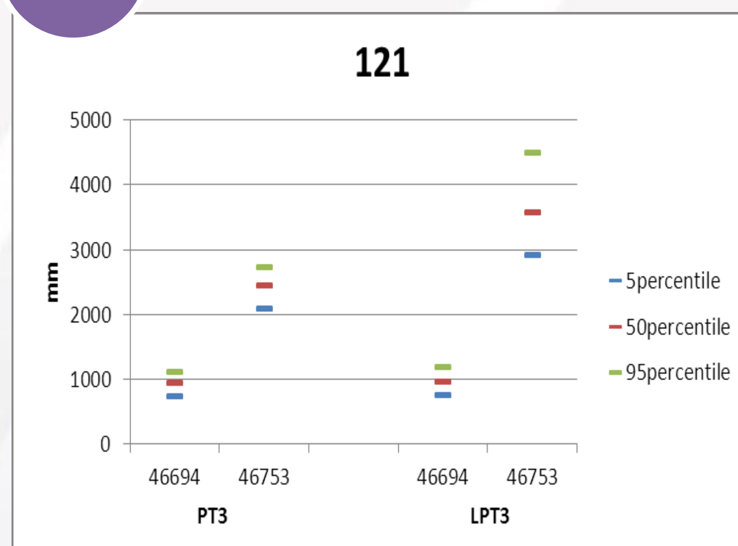
MRI data



1979~2003 (25) + 2015~2039 (25) + 2075~2099 (25) = Total (75)

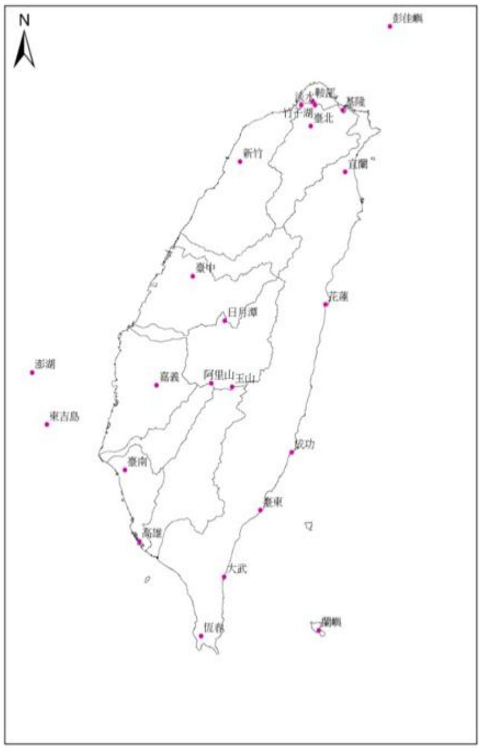


1979 → 2099 = Total(121)

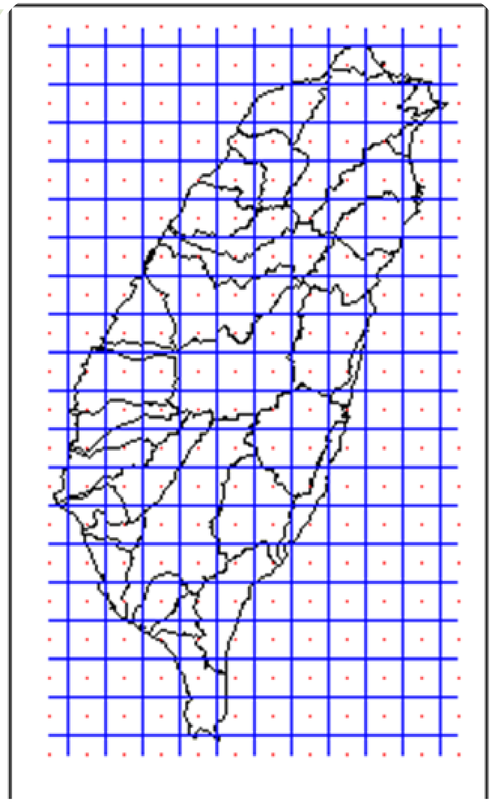


75 years vs. 121 years result:
no apparent differences

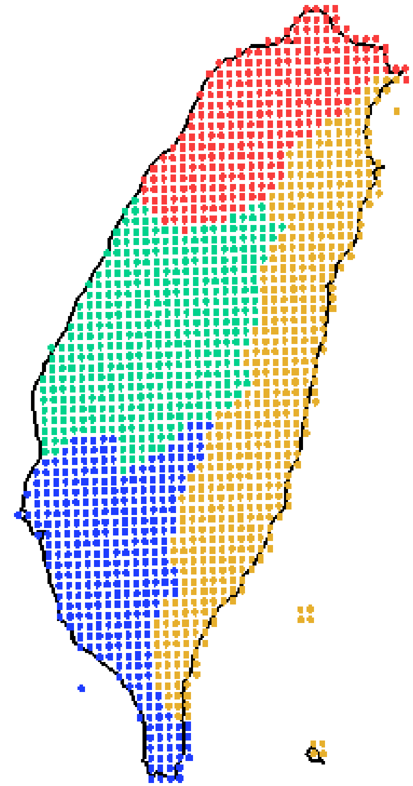
Rainfall gauge station、MRI and WRF data



CWB 23 gauging stations historical data



MRI 20 km



WRF 5km

Compare results of bias correction

Rainfall frequency analysis with bias-corrected MRI data

Rainfall duration: 24hr；return period: 100yrs						
	BC1			BC2		
(year)	1979~2003	2015~2039	2075~2099	1979~2003	2015~2039	2075~2099
(mm)	618.12	431.9	555.44	824.87	846.69	889.32

A higher rainfall was yielded at 2075~2099 period, and a higher flood ratio was demonstrated using BC2.

Flood impact with bias-corrected MRI data

Flow ratio under **24-hr rainfall duration and 100-years return period**						
	BC1			BC2		
(year)	1979~2003	2015~2039	2075~2099	1979~2003	2015~2039	2075~2099
(ratio)	1	0.64	0.88	1	1.03	1.10

Comparison between different data and bias correction approaching

Flow ratio with original model output using KW-GIUH

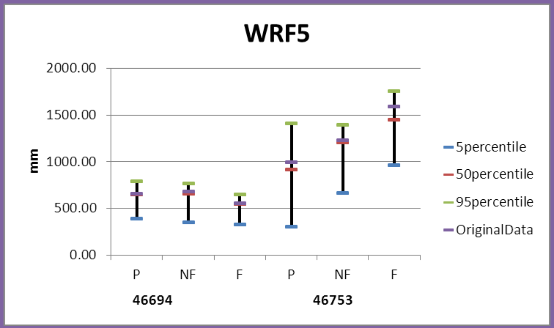
KW-GIUH (original)	Tam-Sui river			Tseng-Wen stream		
	1979-2003	2015-2039	2075-2099	1979-2003	2015-2039	2075-2099
5km WRF	1	1.05	0.81	1	1.25	1.64
20km MRI	1	0.57	0.87	1	1.15	1.91

Flow ratio with bias-corrected data using KW-GIUH

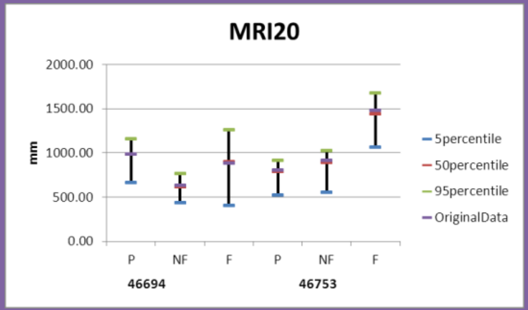
KW-GIUH (BC1)	Tam-Sui river			Tseng-Wen stream		
	1979-2003	2015-2039	2075-2099	1979-2003	2015-2039	2075-2099
5km WRF	1	1.18	0.89	1	0.98	1.43
20km MRI	1	0.63	0.88	1	1.11	1.9

- Results show that obvious difference of flow ratios was yielded with WRF and MRI data.
- Due to hydrological rainfall frequency analysis using annual maximum series, it is necessary to downscale coarse climate data for better regional rainfall information.

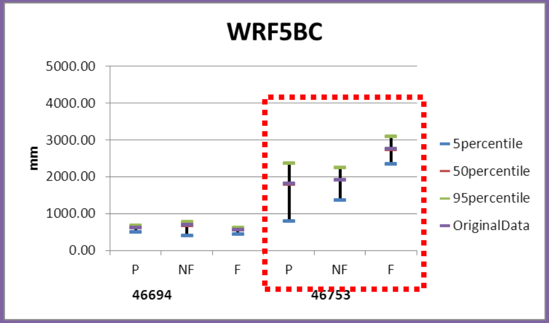
Different data variability



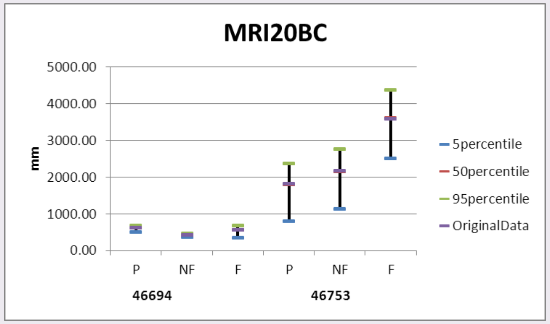
5km WRF(original data)



20kmMRI(original data)



5km WRF with BC1



20kmMRI with BC1

Natural variability at Kee-Lung station (46694) using 5km WRF data：
NF>P>F
Using 20km MRI data：
F> P>NF

Natural variability at A-Li-Shan station(46753 using 5km WRF data：
P>NF> F
Using 20km MRI data：
F =NF> P

Conclusions

NCDR

- The frequency analysis of past observation rainfall data and MRI future climate projection has be done.
- The results show that within different time period or data length, the result of the rainfall frequency analysis are also different, which indicates that the representativeness (or you can say: data quality) of the data dominates the goodness of the results of the frequency analysis.
- Within limited information of the future climate projection, the uncertainty of the result of the frequency analysis and its influence to the impact assessment should be taken into consideration.

Results and discussion (I)

1. **Natural variability of three periods by using MRI data: 2075~2099 >1979~2003 >2015~2039. This implies that data uncertainty at end-of-century(2075~2099) is higher than others.**

2. **Results show that obvious difference of flow ratios was yielded with WRF and MRI data. Due to hydrological rainfall frequency analysis using annual maximum series, it is necessary to downscale coarse climate data for better regional rainfall information.**

3. **Natural variability with original MRI and WRF data is higher than bias-corrected MRI and WRF data.**

4. **Natural variability at Kee-Lung station (46694) using 5km WRF data：NF>P>F ; Using 20km MRI data：F> P>NF**

5. **Natural variability at A-Li-Shan station (46753) using 5km WRF data：P>NF> F; Using 20km MRI data：F =NF> P**

2.Impact and uncertainty of climate change on water resources

- Stream flow impact in wet and dry spell
- Uncertainty of different scenarios
- Uncertainty of weather generation

Flowchart for assessing water resource impact

GCMs after Statistic downscaling

A1B(24) | A2(19) | B1(21)

All GCM

Selection of GCMs

- performance of East Asia monsoon(9 GCMs)
- characteristic of rainfall change rate in wet and dry spell (12 GCMs)

Weather Generator

- Monthly→daily (rainfall、temperature
- （2020-2039、2080-2099）

- Worst case
- Multi-model Ensemble

Simulate stream flow

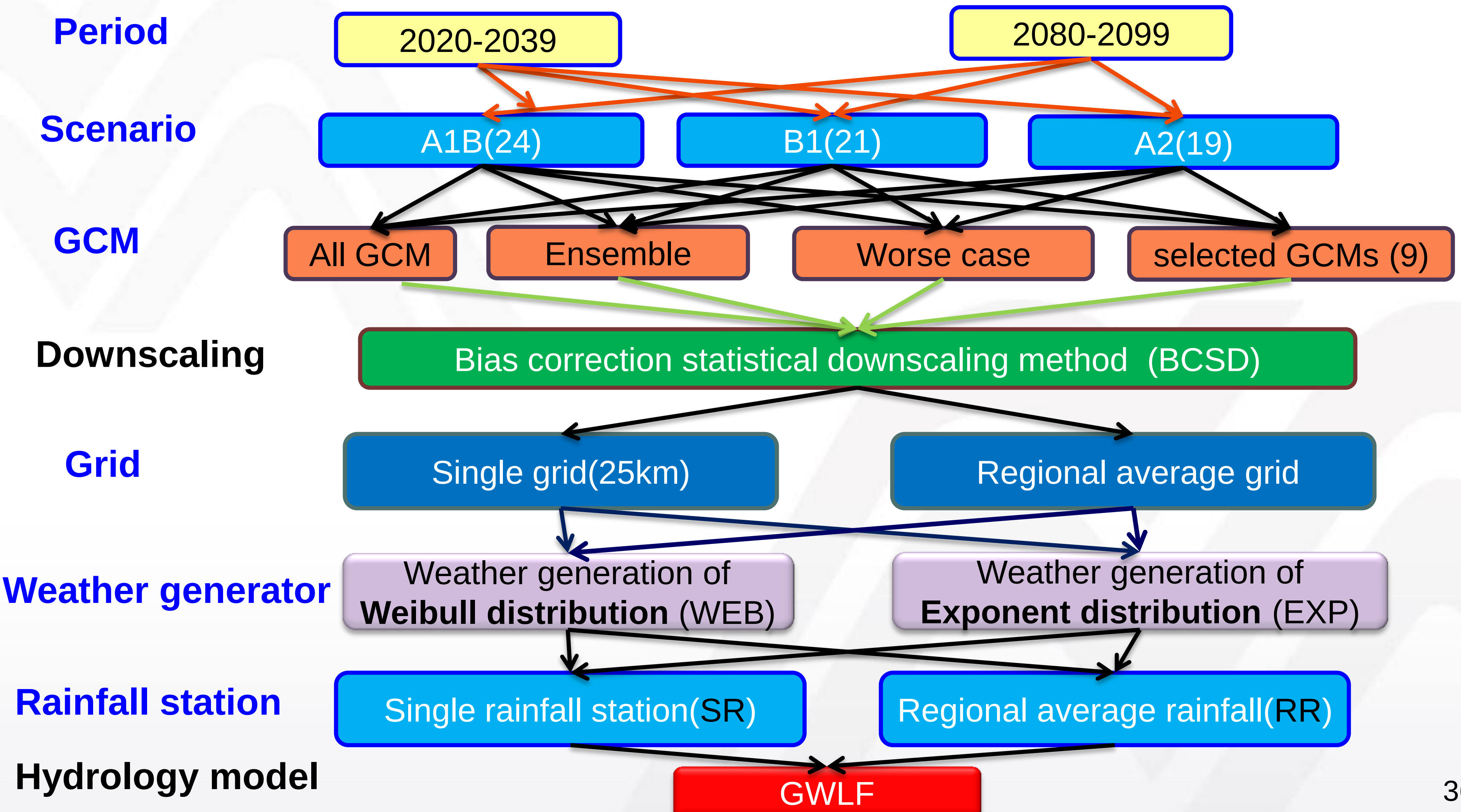
Hydrology model(GWLF)

Uncertainty analyze

- Scenarios(A1B、B1 、A2)
- Choice GCMs
- Weather generator

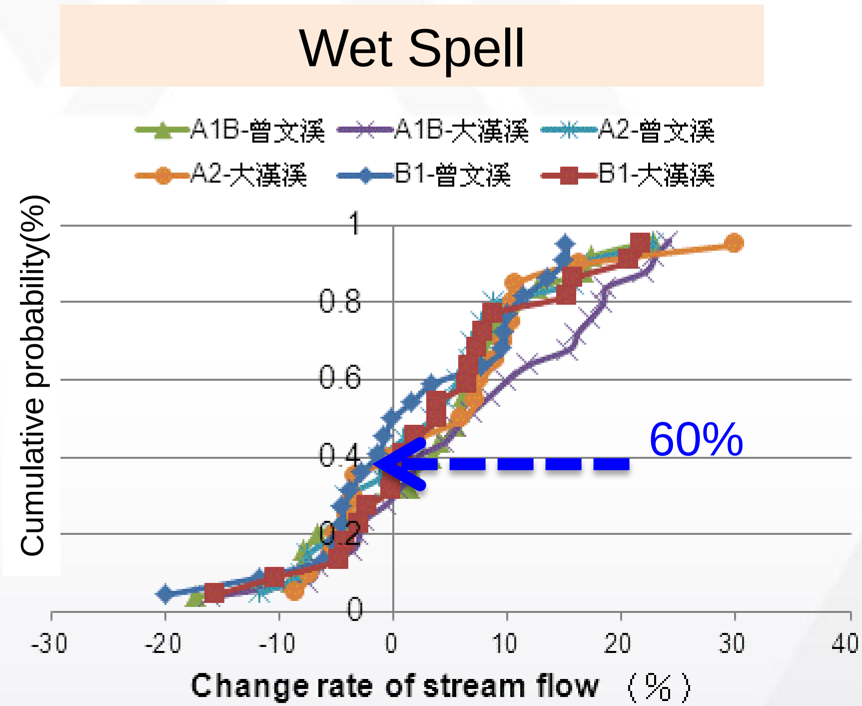
Uncertainty analysis

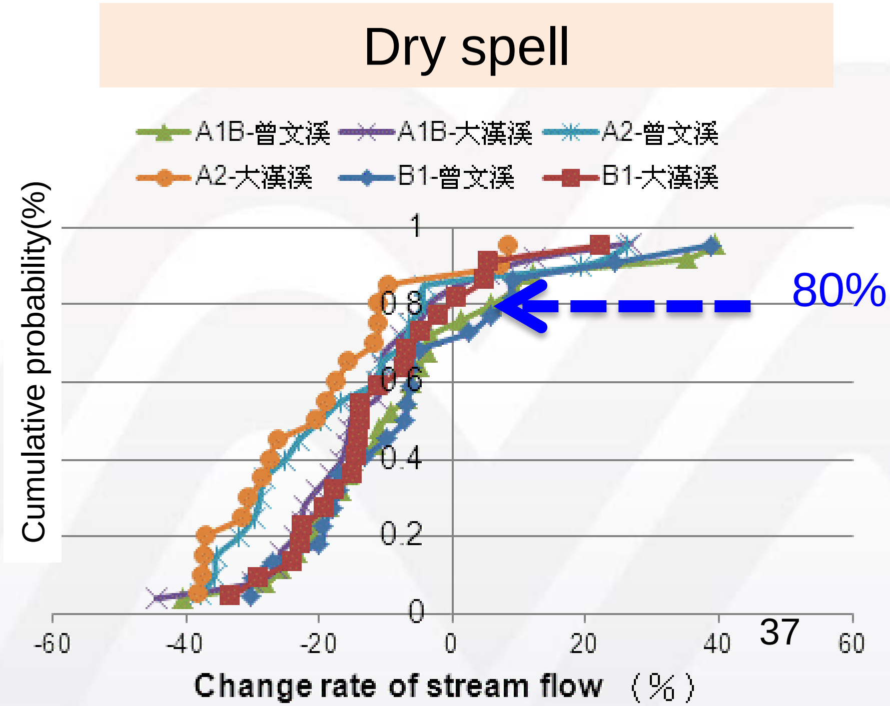
Impact of climate change on stream flow by the combination of various variables.



Change rate of stream flow under climate change

- 60% of GCMs are shown stream flow increase in wet spell and 80% of GCMs decrease in dry spell in near future.
- Range of change rate of stream flow is -20~30% and -40~40%in wet and dry spell respectively.

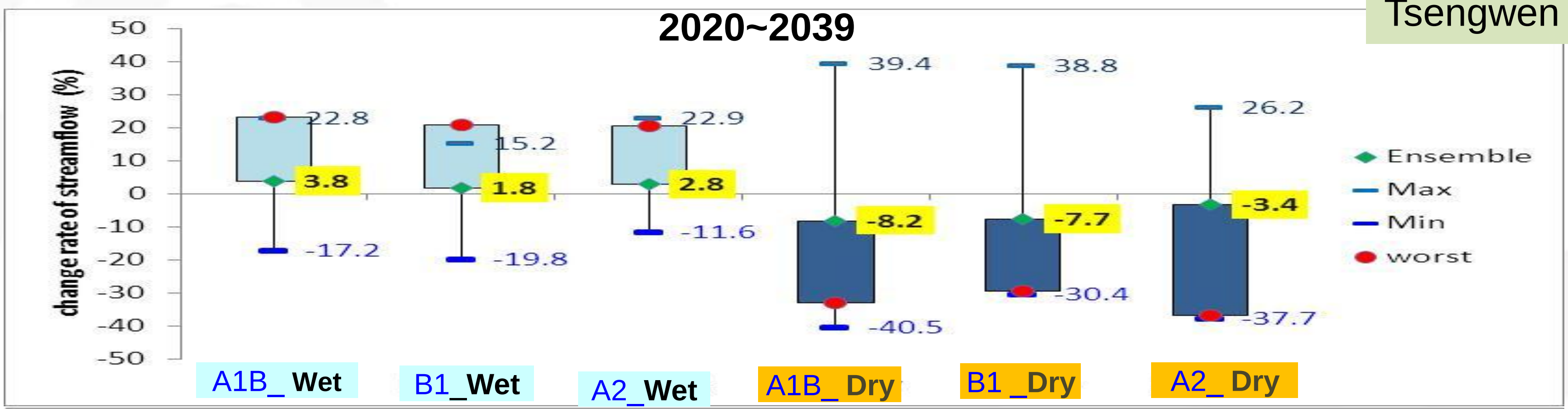


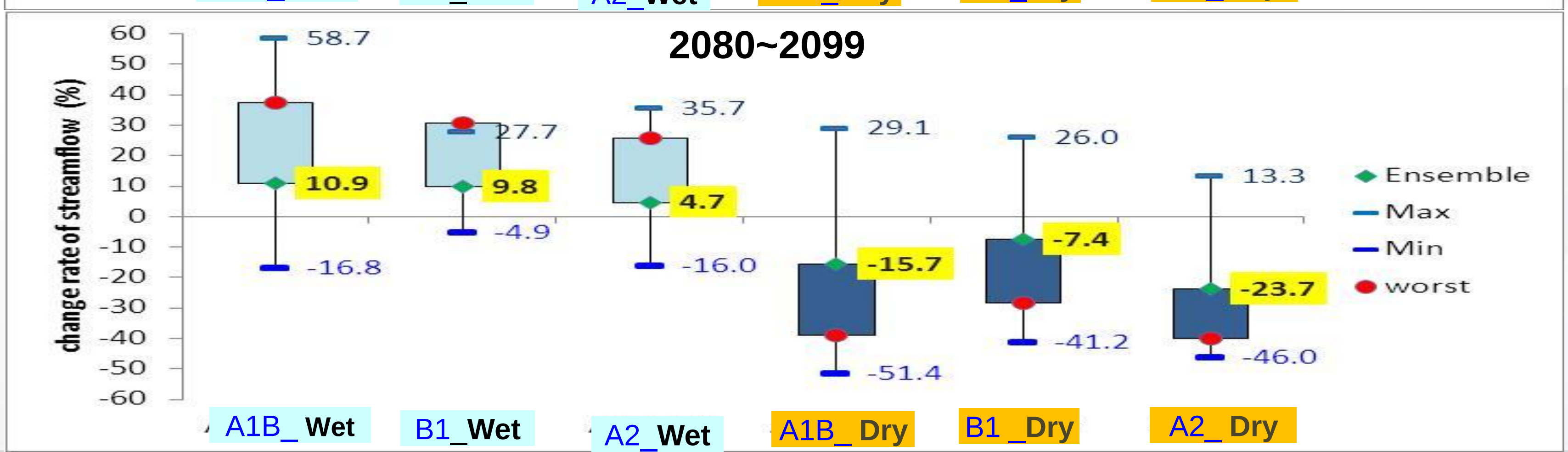


Change rate of stream flow in wet and dry spell

- Multi-model ensemble result is not significant. Change rate of stream flow only 2~4% in wet spell and -3~-8% in dry spell in near future.
- Greater variability of change rate of stream flow is in dry spell
- Variability of change rate: A1B>B1>A2

Tsengwen river





Impact of stream flow due to different scenarios

www.ncdr.nat.gov.tw

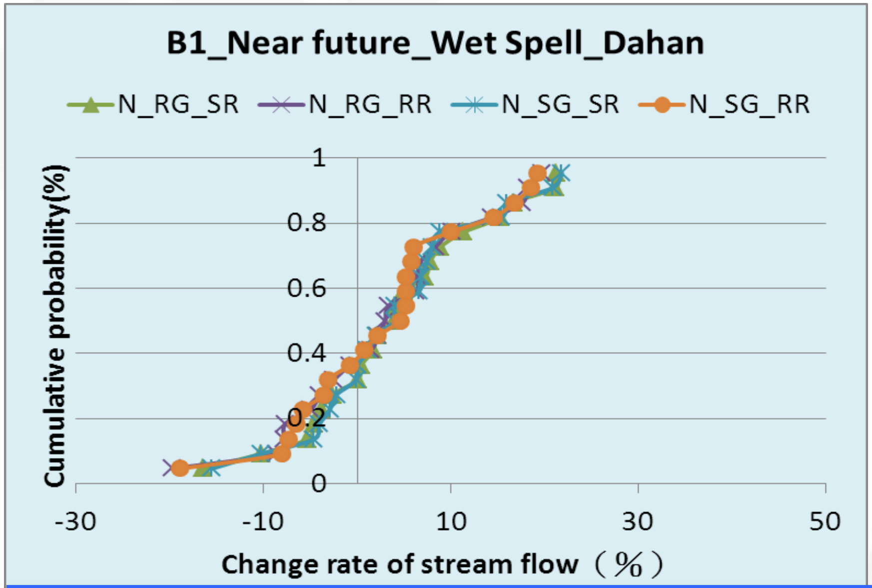
- The more increase in wet season and the more decrease in dry season
- Impact of stream flow is about ±40% under the worst case in the end of 21 century. It is a significant alert for water resource allocation.

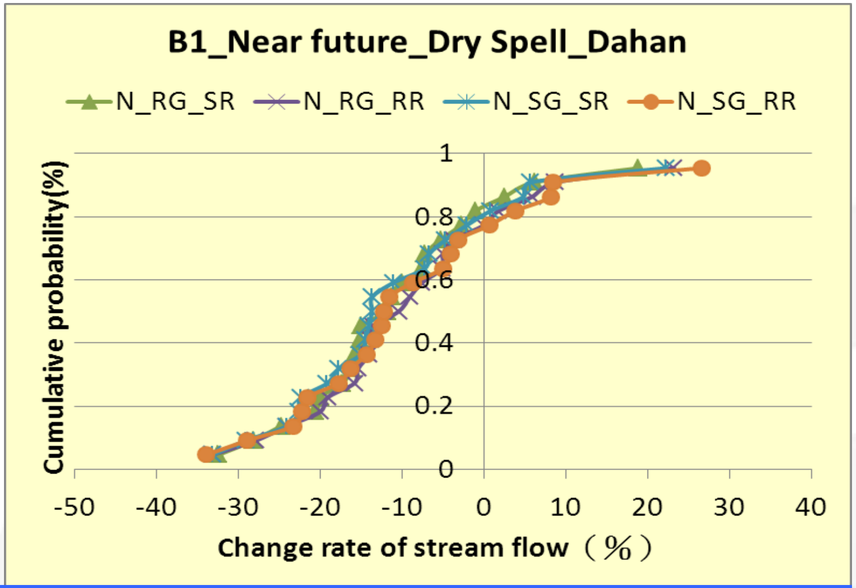
Case study-Tamsui River catchment

Period	Spell	Scenario	Ensemble	Maximum	Minimum	Worst case
2020-2039 (Near future)	Wet spell	A1B	7	24	-16	31
		A2	4	30	-8	25
		B1	4	22	-16	27
	Dry spell	A1B	-13	27	-44	-38
		A2	-21	9	-38	-41
		B1	-11	22	-33	-31
2080-2099 (End of 21st century)	Wet spell	A1B	13	38	-21	46
		A2	5	35	-21	29
		B1	10	37	-15	35
	Dry spell	A1B	-19	14	-48	-47
		A2	-31	-5	-46	-49
		B1	-14	17	-43	-35

Compare results of selection gird and rainfall station

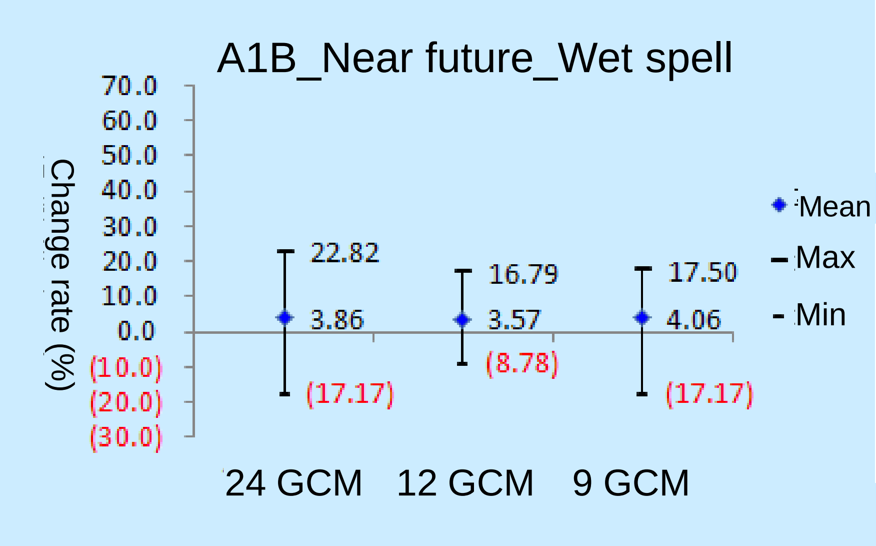
- **The result shown that the combination of** selection gird and rainfall station **is** **not significant difference** for cumulative probability of change rate of stream flow .

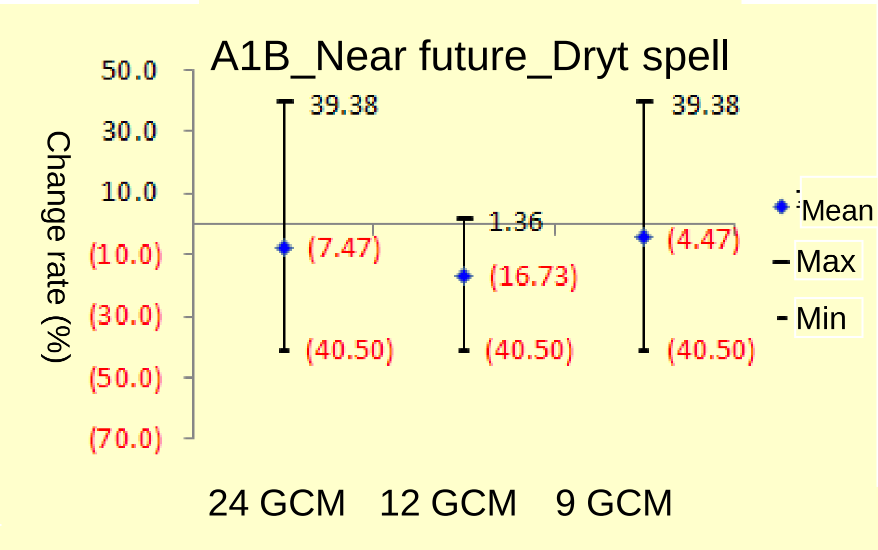




- N_RG_SR : Near Future_ Regional average grid _Single rainfall station
- N_RG_RR : Near Future_ Regional average grid _Regional average rainfall
- N_SG_SR : Near Future_ Single grid _Single rainfall station
- N_SG_RR : Near Future_ Single grid _Regional average rainfall

Compare results of selection GCM





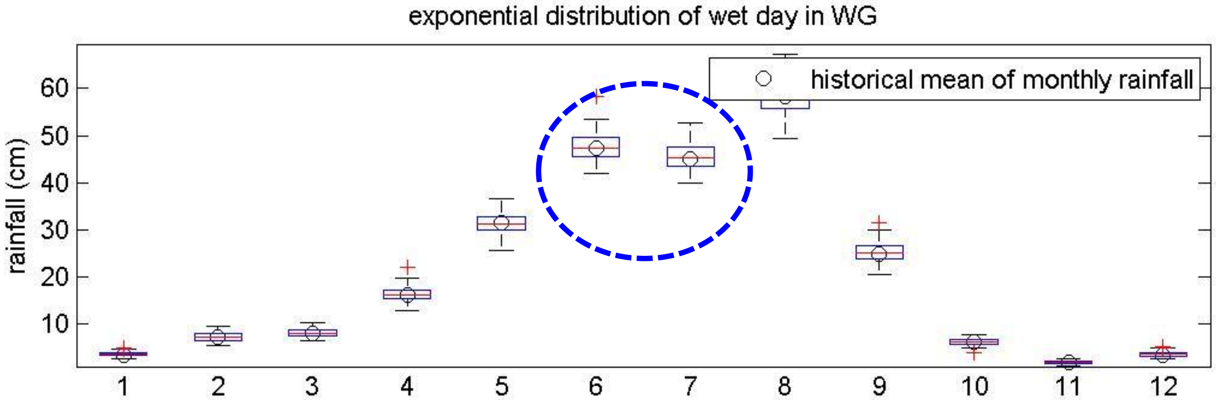
- 24 GCMs: All GCMs
- 12 GCMs: Select GCM by characteristic of rainfall change rate in wet and dry spell
- 9 GCMs: Select GCM based on performance of East Asia monsoon

- The variability and uncertainty of change ratio of stream flow is greater in dry.
- The two methods of choosing GCM all can reduce uncertainty of multi-model in wet spell.

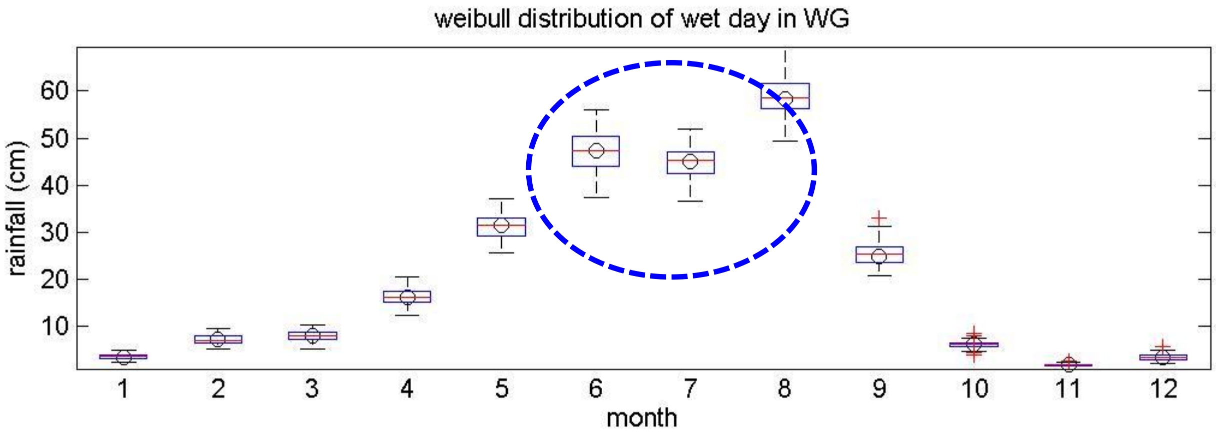
Weather generator of different distribution

- Both exponent and weibull distribution can reproduce historical characteristics of monthly average rainfall.
- Variability of monthly rainfall is greater by Weibull distribution.

Exponent distribution (EXP)



Weibull distribution (WEB)



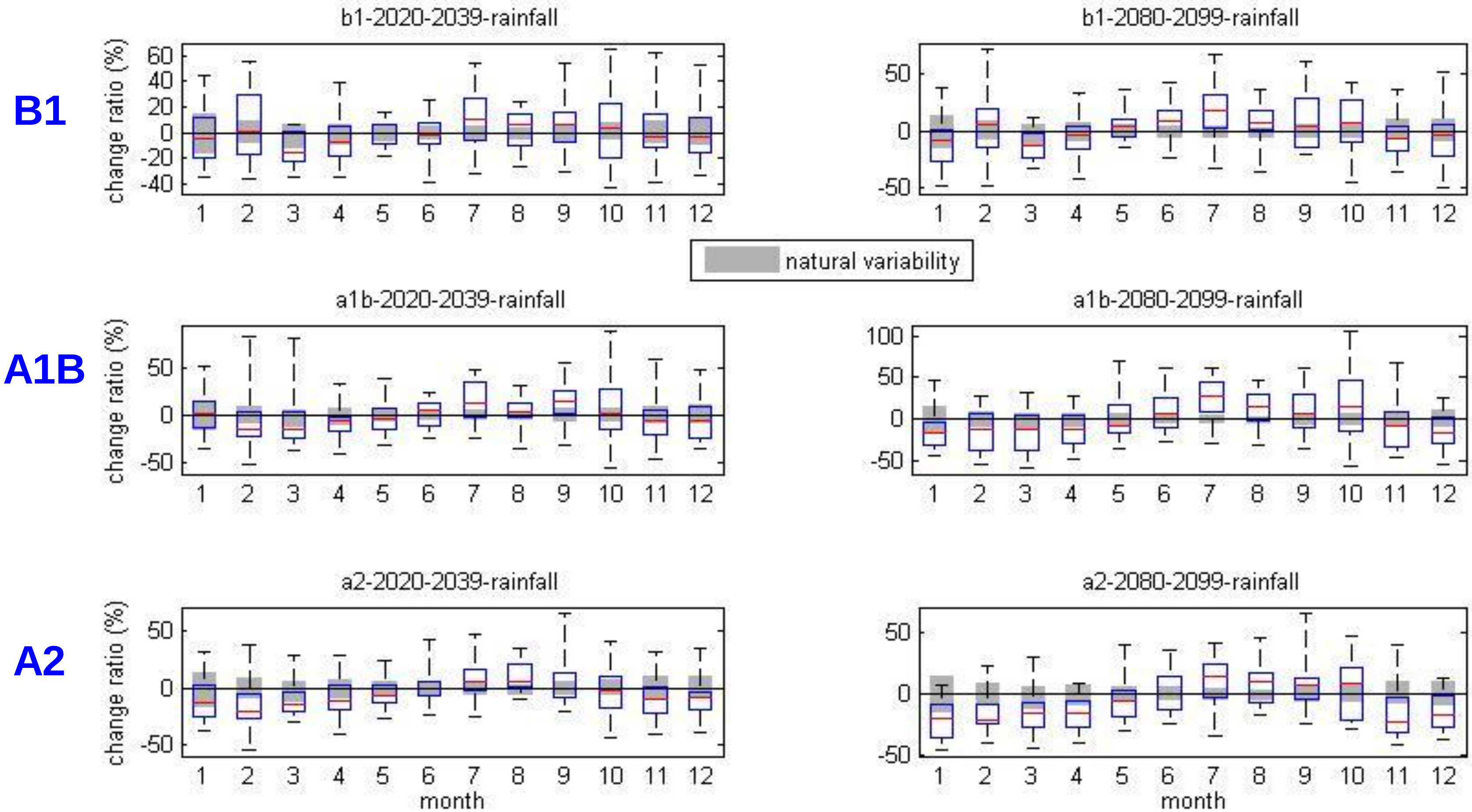
Compare natural variability and different scenarios

NCDR

www.ncdr.nat.gov.tw

The uncertainty in response among different scenarios is greater than the range due to uncertainty in natural variability.

In near future **In end of 21st century**



Results and discussion (II)

1. In stream flow, 60% of GCMs are shown an increase in wet spell, 80% of GCMs are shown a decrease in dry spell in near future.
2. Selection GCM can reduce variability of multi-model, specially in end of 21st century。
3. Variability of stream flow in A1B scenarios is greater than other scenarios (A2,B1)
4. The uncertainty among different scenarios is greater than the range due to uncertainty in natural variability.
5. Both exponential and Weibull distributions can reproduce historical characteristics of monthly average rainfall. But variability of Weibull distribution is greater.

Final Conclusions

www.ncdr.nat.gov.tw

- MRI data uncertainty at end-of-century(2075~2099) is higher than others.
- Natural variability is higher than bias-corrected MRI and WRF data.
- 60% of GCMs are shown streamflow increased in wet spell and 80% of GCMs are shown a decrease in dry spell in near future.
- Range of change rate of stream flow is -20~30% and -40~40%in wet and dry spell, respectively
- The impact of stream flow is A1B >B1> A2 scenarios

www.ncdr.nat.gov.tw

Thank you for your attention.