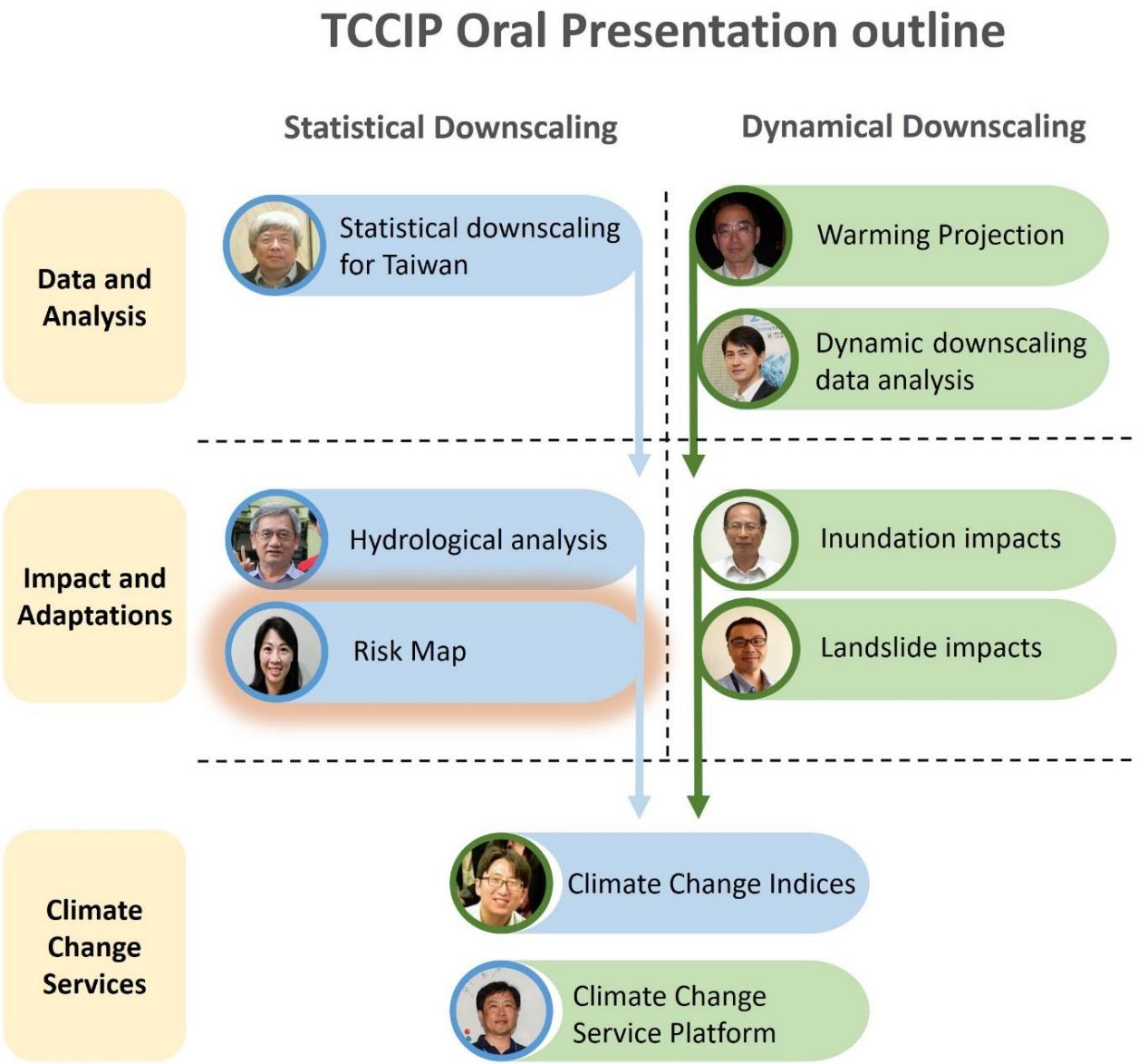
Applied Statistical Downscaling Data on Risk Map of Flood Disasters

National Science & Technology Center for Disaster Reduction

Yun-Ju Chen, Hsuan-Ju Lin, Jun-Jih Liou, Zong-Syun Lian

2019.10.22

Roadmap of TCCIP data



Outlines

- Introduction
  - Purpose of risk map
  - Process of risk map development
- Method of flood risk map assessment
- Results of risk map
- Uncertainty of risk map
  - GCM Model consistency
- Conclusion

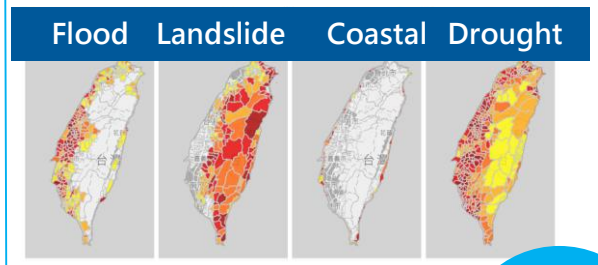
Propose of study

- To provide climate-change disaster risk information in terms of impact extents and spatial distribution.
  - Impact extents: indicator score ranking
  - Spatial distribution ➔ reveal disaster hot spot
- To applied daily data of statistical downscaling on disaster risk map

Disaster risk map evolution

1st edition-AR4 Risk map

Dynamic downscaling, MRI-**A1B** scenario from Japan, four disaster risk maps in the **near future** and the **end of the century**



2013 yr.

2015 yr.

2017 yr.

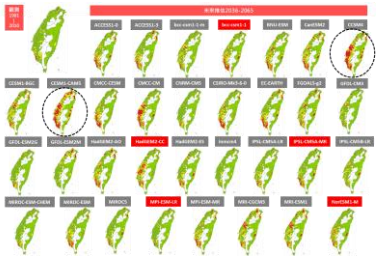
2019 yr.

2nd edition-AR5 Ris kmap

Dynamic downscaling, MRI-**RCP8.5** scenario, the **end of the century, National and City scale risk map**

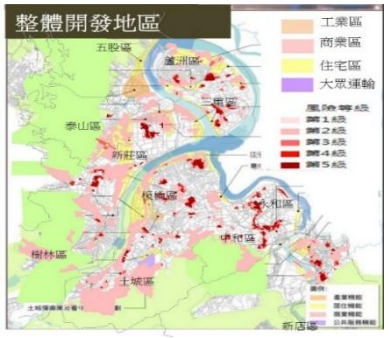
3rd edition-AR5 Riskmap

Statistical downscaling, 33 GCMs, **middle** of the 21st century.



Risk map by different space scale

Multi-unit of estimate population applied to risk map, applied risk map on regional plan



1st edition-AR4 Risk map

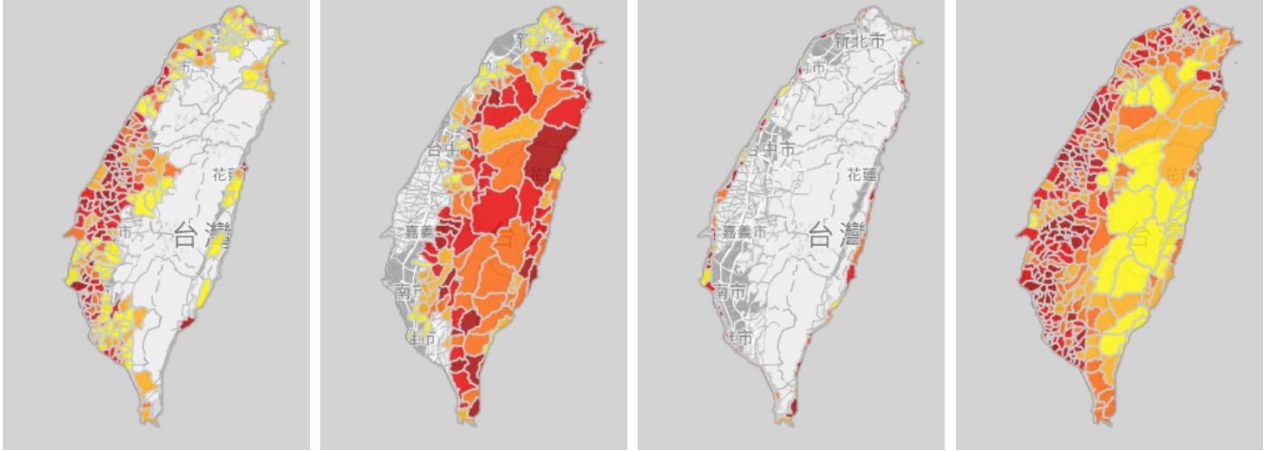
Data :MRI-JMA AGCM -**A1B** scenario from Japan **Dynamic** downscaling,5km, four disaster risk maps in the **near future** and the **end of the century(25 years)**

科技部 災害管理資訊研發應用平台 Ministry of Science and Technology > 氣候變遷之災害衝擊與調適

Only one GCMs
High uncertainty

dmip.tw/Lthree/home.aspx

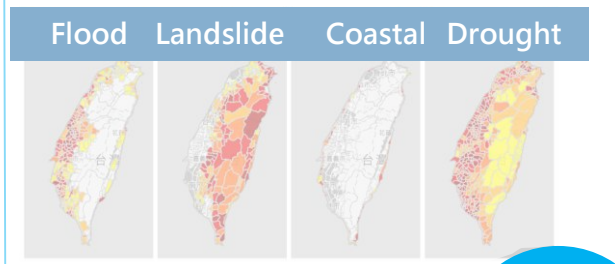
淹水災害風險地圖	坡地災害風險地圖	海岸災害風險地圖	乾旱災害風險地圖
近未來（2015-2039年）	近未來（2015-2039年）	近未來（2015-2039年）	近未來（2015-2039年）



Disaster risk map development process

1st edition-AR4 Risk map

Dynamic downscaling, MRI-A1B scenario from Japan, four disaster risk maps in the near future and the end of the century



2013 yr.

2015 yr.

2nd edition-AR5 Risk map

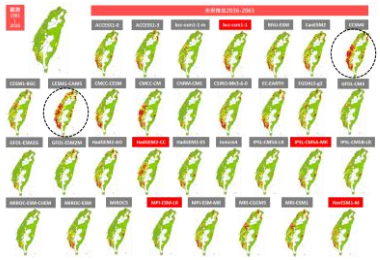
Dynamic downscaling, MRI-RCP8.5 scenario, the end of the century, National and City scale risk map

2017 yr.

2019 yr.

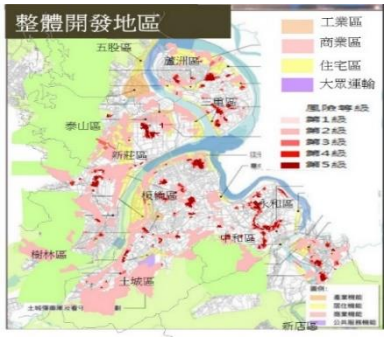
3rd edition-AR5 Riskmap

Statistical downscaling, 33 GCMs, the middle of the 21st century.



Risk map by different space scale

Multi-unit of estimate population applied to risk map, applied risk map on regional plan



2nd edition-AR5 Risk map

- Dynamic downscaling, MRI-**RCP8.5** scenario, the end of the century, National and City scale risk map

https://dra.ncdr.nat.gov.tw/Frontend/Tools/TotalRisk?RiskType=Flooding

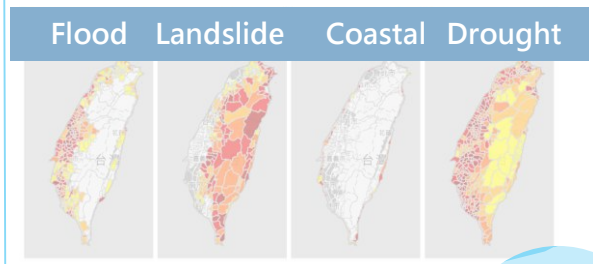
2nd edition-AR5 Risk map

- Publish 1. “Atlas of Disaster Risk Map under Climate Change”
  2. “Q&A for Disaster Risk Map under Climate Change”

Disaster risk map development process

1st edition-AR4 Risk map

Dynamic downscaling, MRI-A1B scenario from Japan, four disaster risk maps in the near future and the end of the century



2013 yr.

2015 yr.

2017 yr.

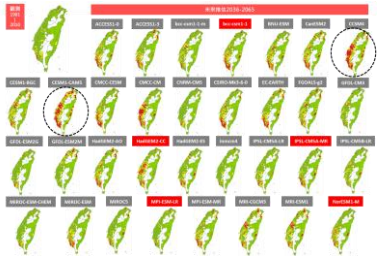
2019 yr.

2nd edition-AR5 Riskmap

Dynamic downscaling, MRI-RCP8.5 scenario, the end of the century, National and City scale risk map

3rd edition-AR5 Riskmap

Statistical downscaling, 33 GCMs, the middle of the 21st century.



Improved and Applied Risk map by different space scale

Multi-unit of estimate population applied to AR5 risk map, applied risk map on regional plan

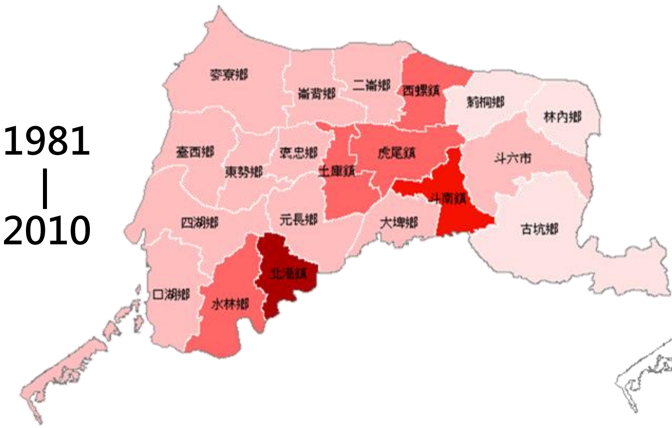
AR5 Risk map detailed geospatial-YunLin county

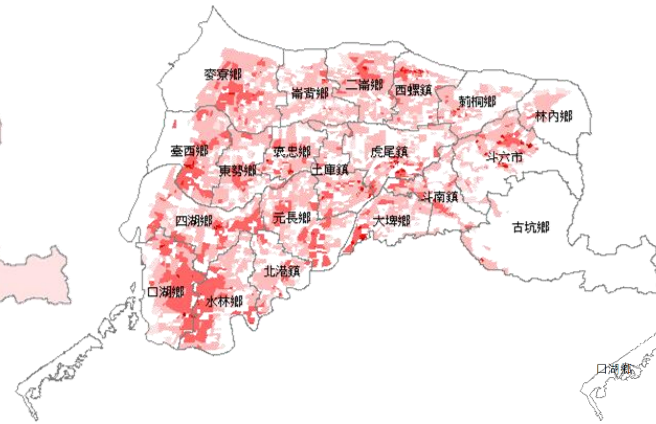
Township scale

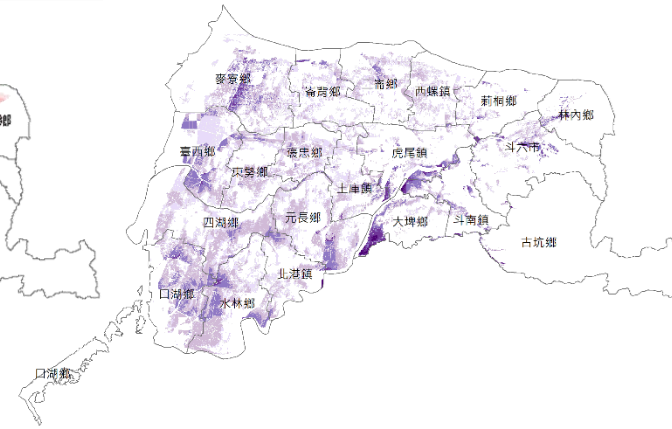
Multi-unit of estimate population

Vulnerability-Exposure 40m×40m grid

Observation 1981 | 2010

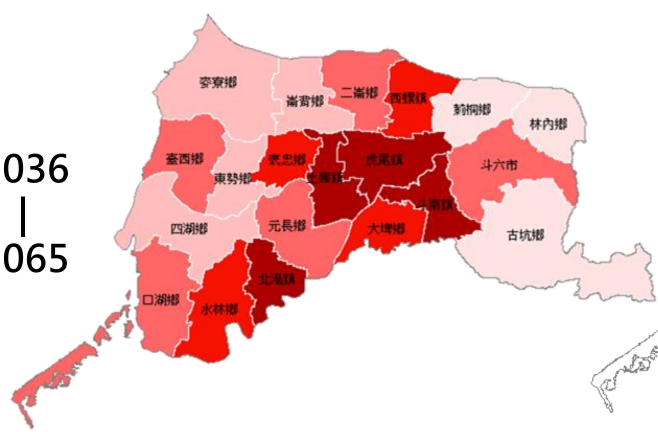




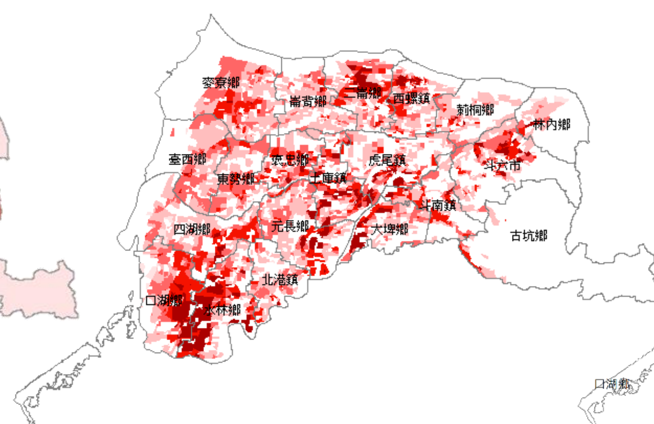


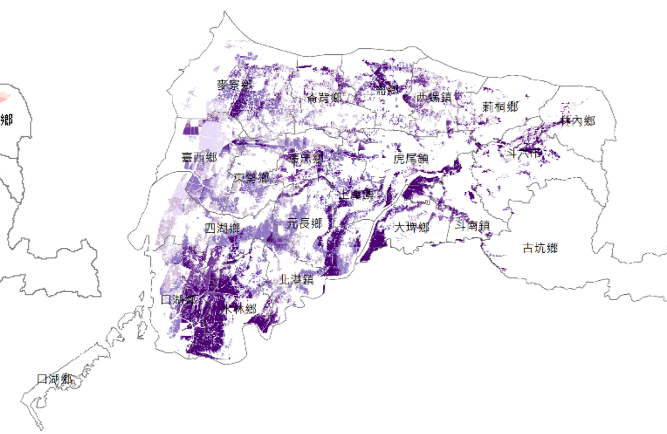
Middle of century 2036 | 2065

模式bcc-csm1-1_r1_lv



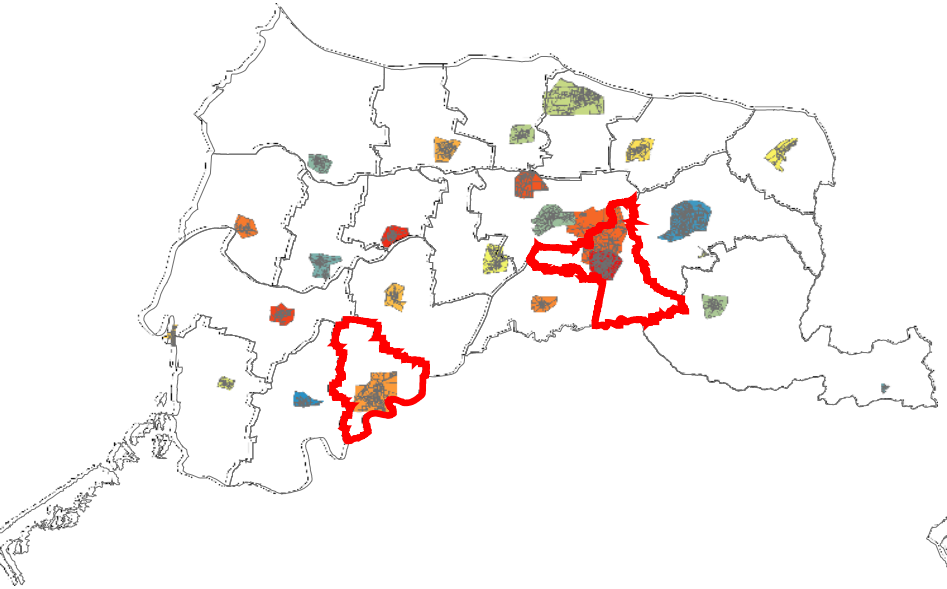
模式bcc-csm1-1_r1_lv



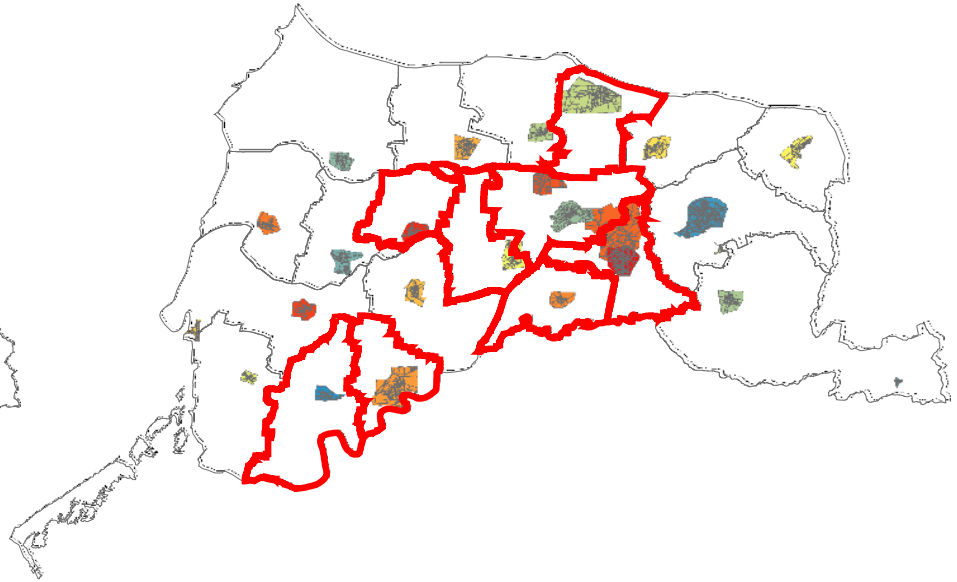


Risk map overlap urban region plan

Observation 1981-2010



Middle of century 2036-2065



Above Level 3

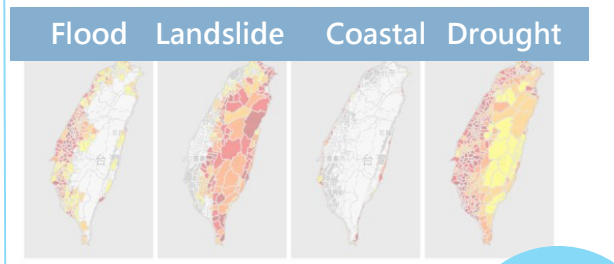
Some of regional are located in high risk level

Township scale

Disaster risk map development process

1st edition-AR4 Risk map

Dynamic downscaling, MRI-A1B scenario from Japan, four disaster risk maps in the near future and the end of the century



2013 yr.

2015 yr.

2017 yr.

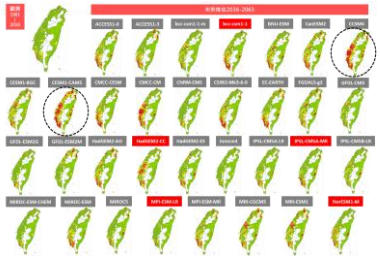
2019 yr.

2nd edition-AR5 Riskmap

Dynamic downscaling, MRI-RCP8.5 scenario, the end of the century, National and City scale risk map

3rd edition-AR5 Riskmap

Statistical downscaling, 33 GCMs, the middle of the 21st century



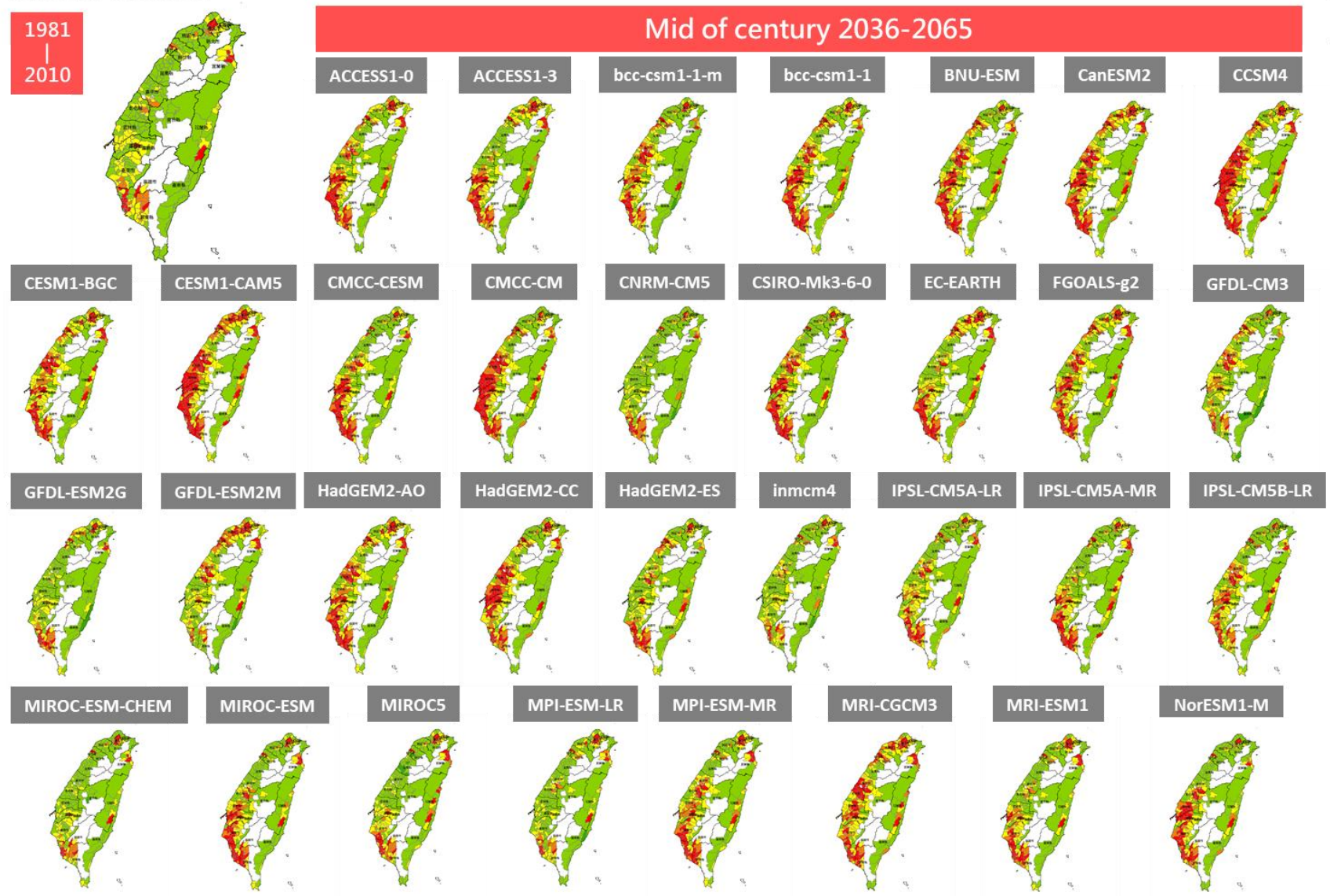
Risk map by different space scale

Multi-unit of estimate population applied to AR5 risk map, applied risk map on regional plan

Improve of risk map

- High uncertainty of single GCM(MRI) and single scenario(RCP8.5)
  - Appling multi-model and statistical downscaling
- Considering user’s demand
  - Middle of century (2036-2065) and different spatial scale is analyzed.
- Update 3rd potential flood map by WRA in 2018. (SOBEK-flood simulation model)

3nd edition-AR5 Riskmap



Outlines

- Introduction
  - Purpose of risk map
  - Process of risk map development
- **Method of flood risk map assessment**
- Results of risk map
- Uncertainty of risk map
  - GCM Model consistency
- Conclusion

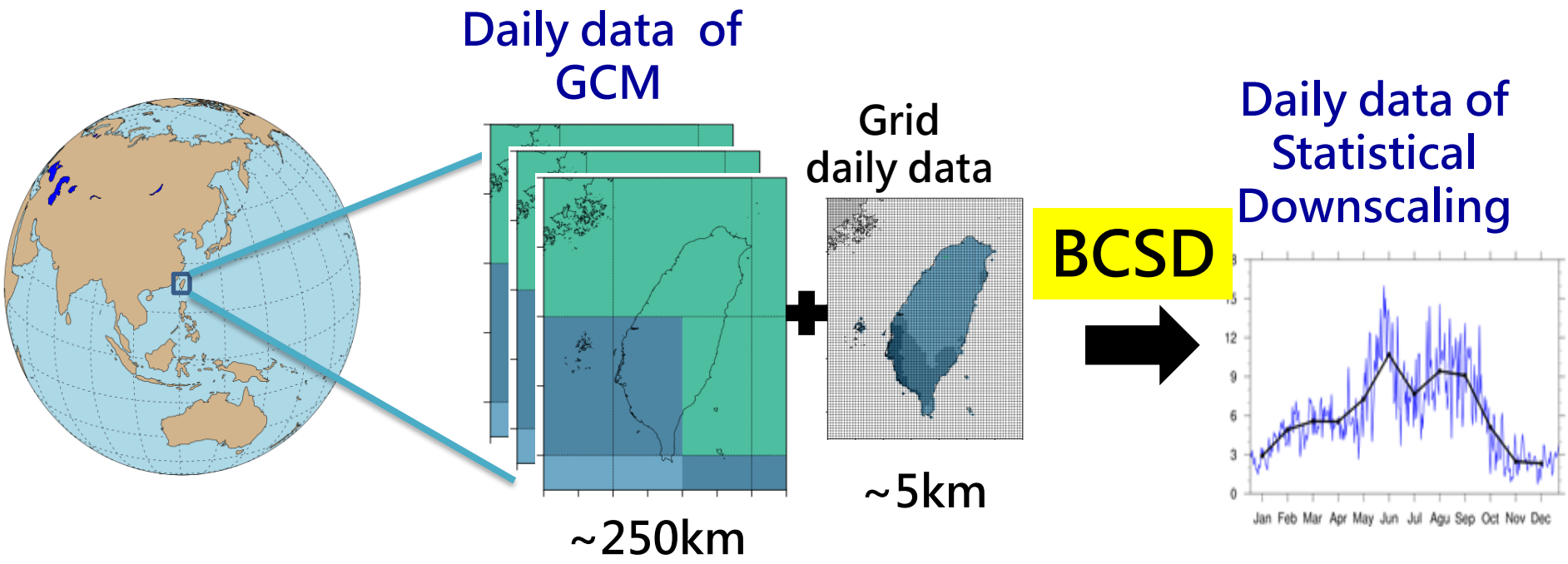
Downscaling Data

- Multi-scenarios, multi-GCMs and future projection 100 years by statistical downscaling were estimated.
- These data can be analyzed the uncertainty of GCMs.

	Dynamic downscaling 2013	Dynamic downscaling 2015	Statistical downscaling 2019
Scenario	A1B	RCP8.5	RCP8.5、RCP4.5、RCP2.6、RCP6.0
Number of GCM	1(MRI)	1(MRI)	33、30、22、17
Timely	Typhon event Hourly	Typhon event Hourly	Continuous Daily
Period	• Baseline(1979-2003)、 • Near Future(2015-2039) • End of century (2075-2099)	• Baseline(1979-2003)、 • End of century (2075-2099)	Baseline(1981-2010)、Middle of century(2036-2065)、End of century (2071-2100)

Statistical Downscaling

- Bias correction statistical downscaling method (BCSD)
- Spatial coordination: 5Km resolution



18

Applied fields of daily data of statistical downscaling

Disaster
Flood Risk Map

Agriculture
Impact of Rice production

Public Health
Potential Distribution of Dengue Fever

Hydrology
Frequency

Forest ecology
Impact of growth conditions of plant

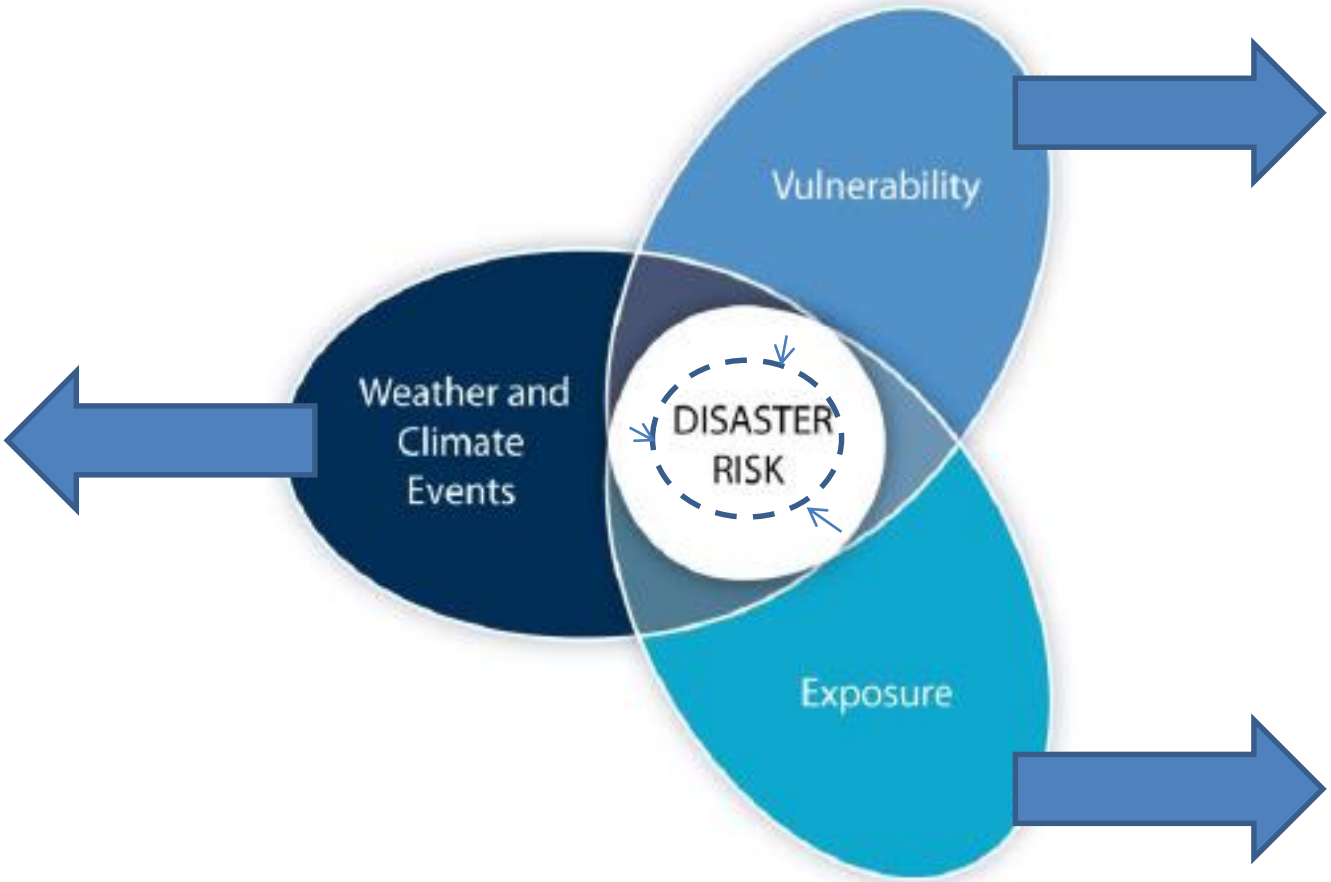
Daily Data of Statistical Downscaling

- There are 33 GCMS for RCP8.5 by bias correction statistical downscaling method (BCSD)
- Estimated period: middle of century (2036~2065 year) and the end of century (2070~2099 year)
- The exceedance probability of design rainfalls (650mm/day) is calculated.

GCM Model Name			
ACCESS1-0	CMCC-CESM	GFDL-ESM2M	MIROC-ESM-CHEM
ACCESS1-3	CMCC-CM	HadGEM2-AO	MIROC-ESM
rbcc-csm1-1-m	CNRM-CM5	HadGEM2-CC	MIROC5
bcc-csm1-1	CSIRO-Mk3-6-0	HadGEM2-ES	MPI-ESM-LR
BNU-ESM	EC-EARTH	inmcm4	MPI-ESM-MR
CanESM2	FGOALS-g2	IPSL-CM5A-LR	MRI-CGCM3
CCSM4	GFDL-CM3	IPSL-CM5A-MR	MRI-ESM1
CESM1-BGC	GFDL-ESM2G	IPSL-CM5B-LR	NorESM1-M
CESM1-CAM5			

Risk Definition

- Driving forces of Risk
  Reduced disaster risk method

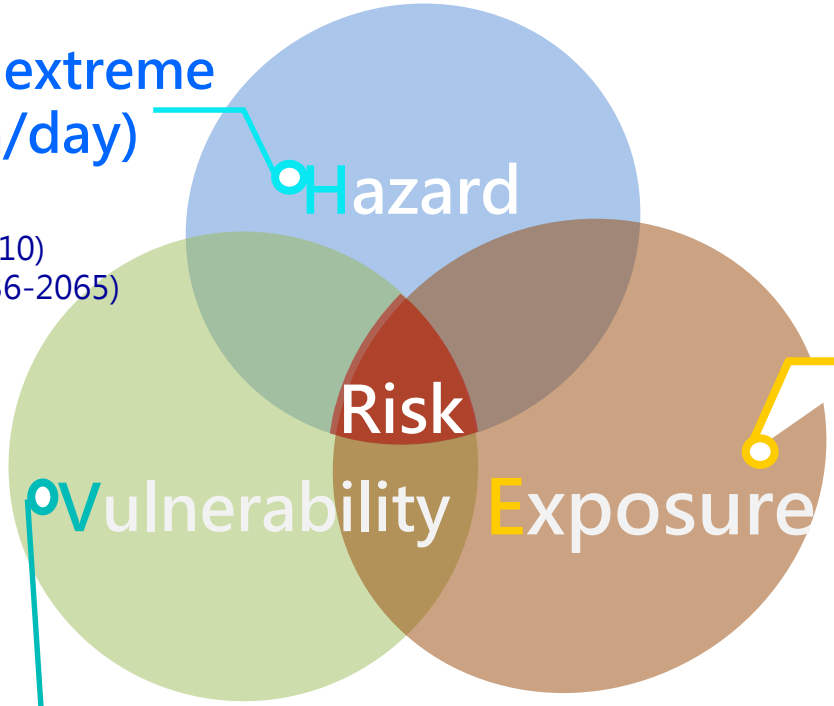


(IPCC SREX, 2012)

Risk Indicator

Probability of extreme rainfall(650mm/day)

- period:
  Observation (1981-2010)
  Future projection (2036-2065)



- Population density (Township)
  - 2018 yr.
  - 2036 yr.

- 650mm/24hr Potential of flooding area (WRA)

Risk Map	Data source	Data year
Hazard	TCCIP-Statistical Downscaling	2018
Vulnerability	Water resource agency-Potential of flooding map	2016
Exposure	Present：Ministry of the Interior	2018
	Future projection ：National Taipei University	2036

Method of Indicator Calculation

Probability of extreme rainfall

observation | 33 GCMs future projection

Standardizing

Hazard Level

Potential of flooding map

650mmPotential of flooding map (WRA)

Standardizing

Vulnerability Level

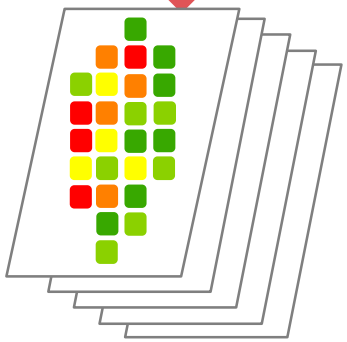
Population density

Present (2018 year) | Future (2036year)

Standardizing

Exposure Level

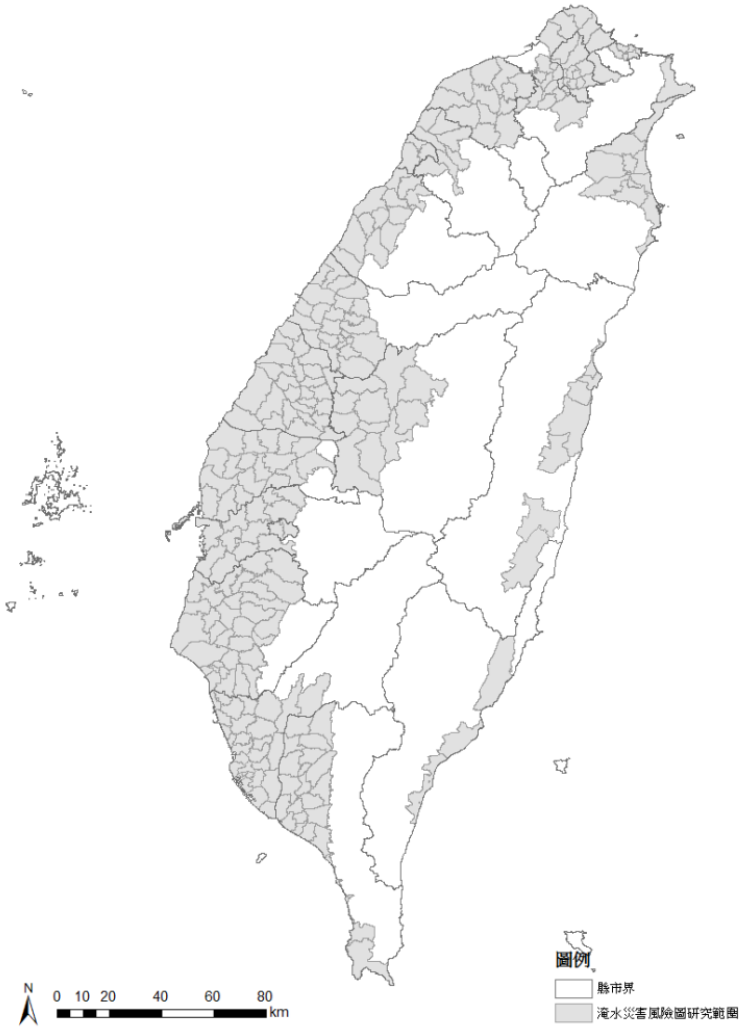
Risk=Hazard × Vulnerability ×Exposure



Disaster risk map of observation and 33 GCM

Method -Study Area

Flooding- Analysis 314 townships in flood risk area .
About 90% townships in Taiwan was assessed.

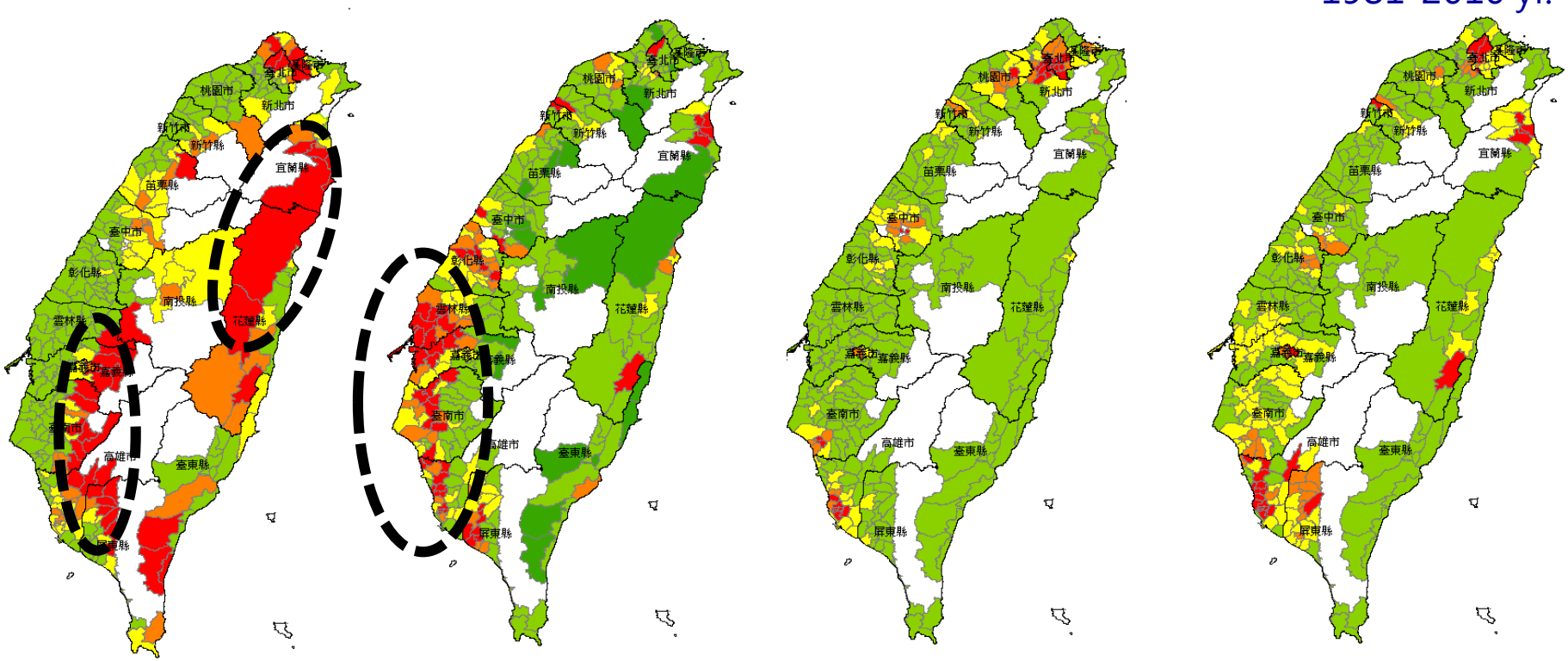


Result of risk map

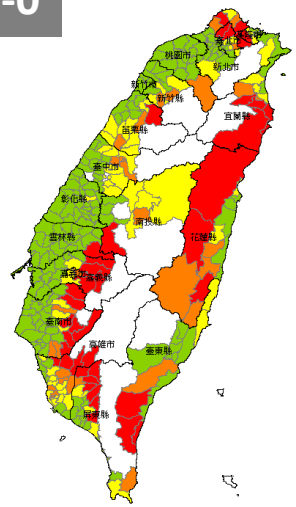
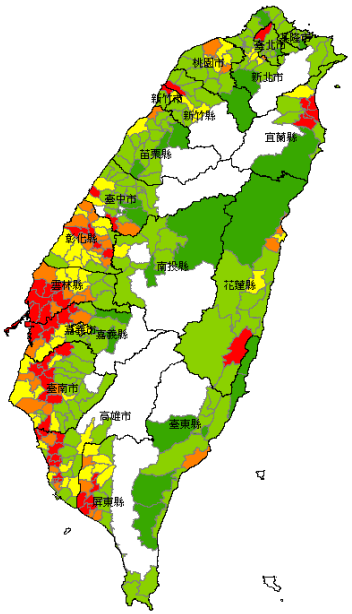
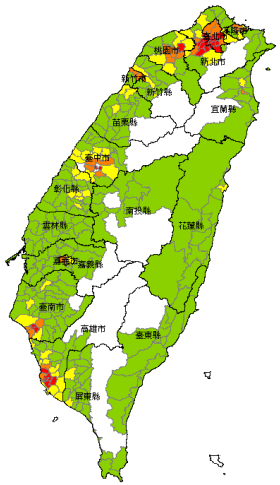
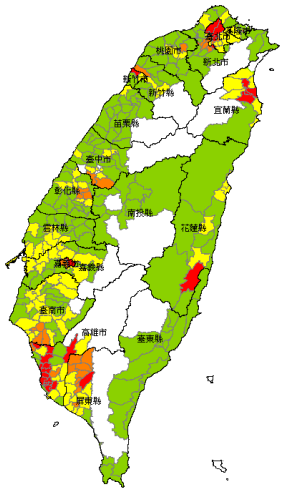
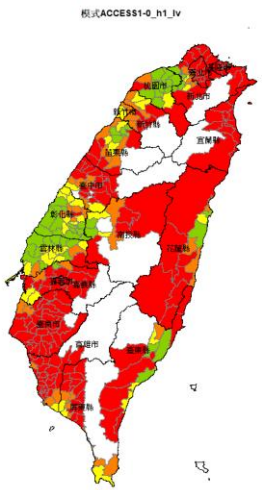
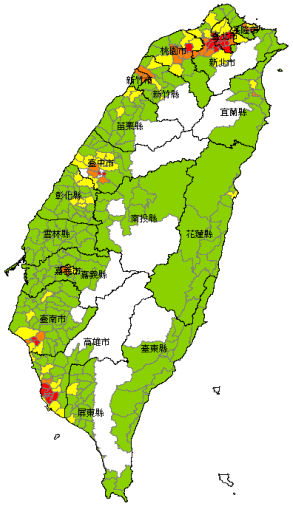
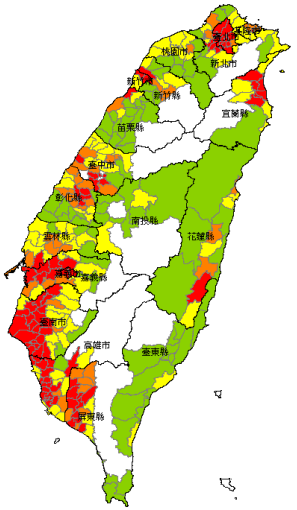
Observation Flood Risk Map

Hazard	Vulnerability	Exposure	Risk
The mountain area has extrema rainfall	Potential flooding in the coastal southwest township.	The more populous area is urban cities	Kaohsiung and Taipei have high flood risk

1981-2010 yr.

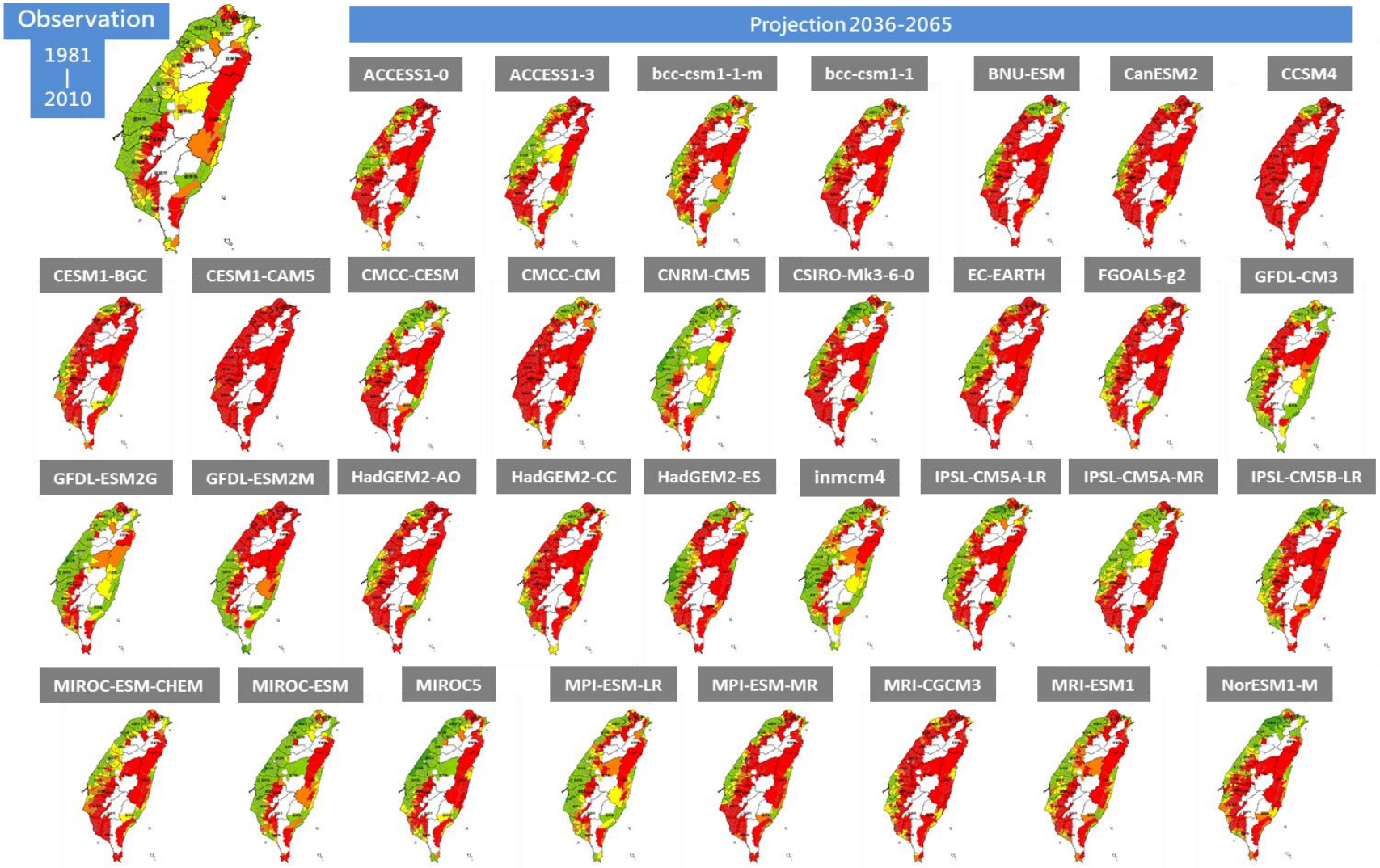


Risk Map under Climate Change

	Hazard	Vulnerability	Exposure	Risk Map
ACCESS1-0				
Observation 1981 — 2010			present 	
Mid of century 2036 — 2065			2036 year 	

Flood Hazard Map

- Probability of extreme rainfall will increase in western Taiwan based on result most of GCMs.



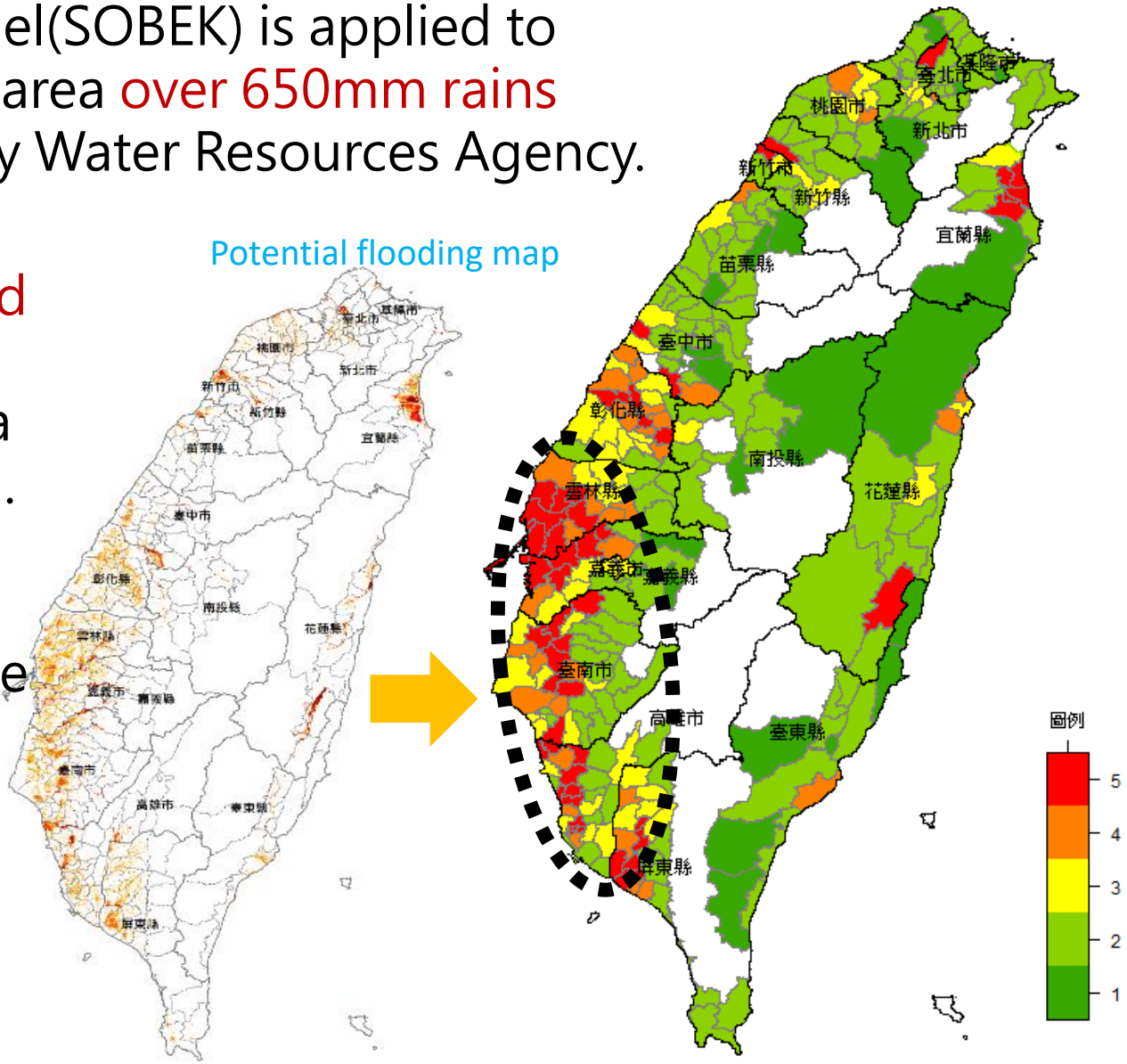
Flood Vulnerability Map

- A inundation model(SOBEK) is applied to simulate flooding area over 650mm rains during 24 hours by Water Resources Agency.

- Flooding depth and area of township are considered as a vulnerability index .

- High vulnerability of flooding damage is in central and southern coastal townships.

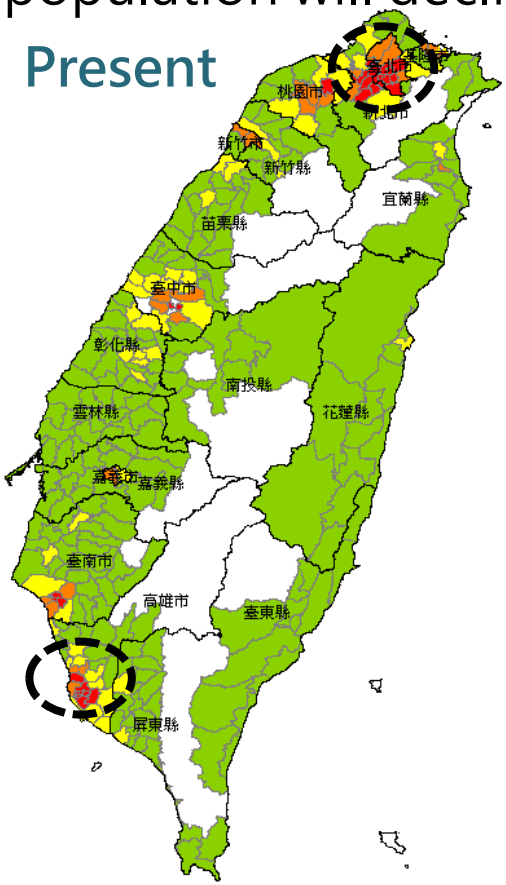
Potential flooding map



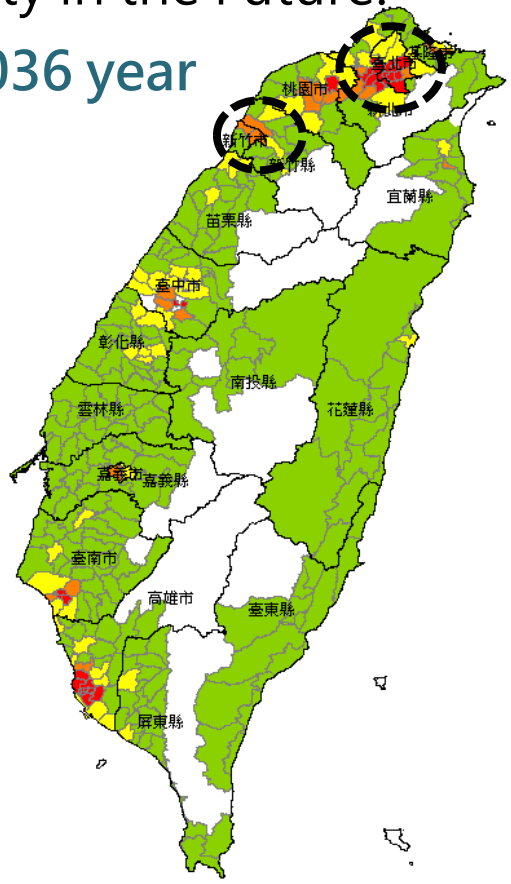
Exposure Map

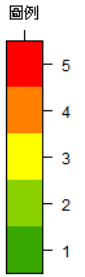
- The population density of township is as exposure index. **High population density** means that many people will exposure in flooding hazard, so **urban city** has high exposure.
- Highest population exposure is in Taipei, New Taipei and Kaohsiung city. The population will decline in Taipei city in the Future.

Present



2036 year

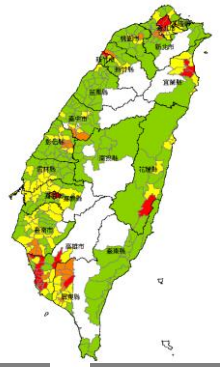




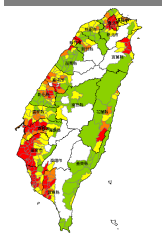
Flood Risk Map

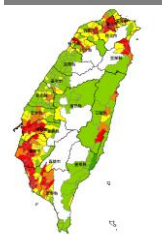
Observation

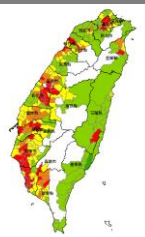
1981 | 2010

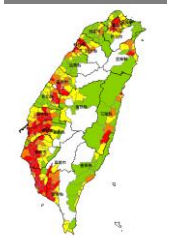


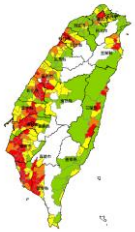
Mid of century 2036-2065

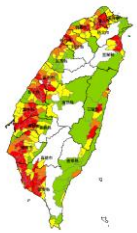
ACCESS1-0 

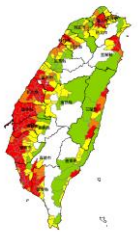
ACCESS1-3 

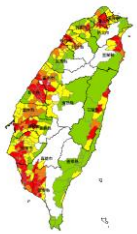
bcc-csm1-1-m 

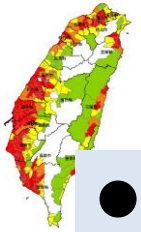
bcc-csm1-1 

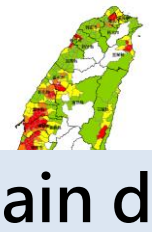
BNU-ESM 

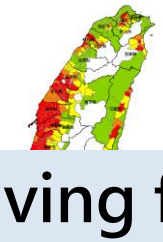
CanESM2 

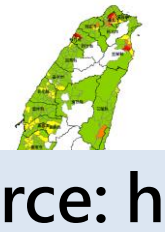
CCSM4 

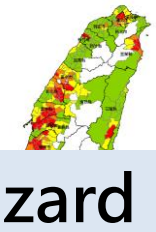
CESM1-BGC 

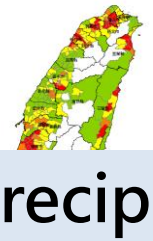
CESM1-CAM5 

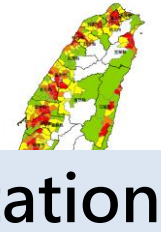
CMCC-CESM 

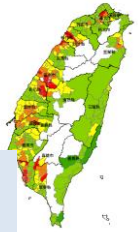
CMCC-CM 

CNRM-CM5 

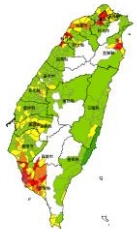
CSIRO-Mk3-6-0 

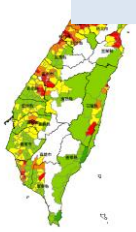
EC-EARTH 

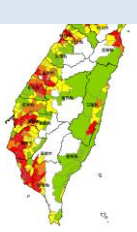
FGOALS-g2 

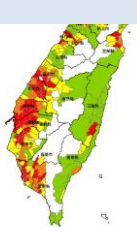
GFDL-CM3 

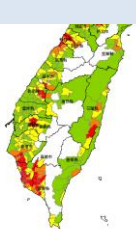
- Main driving force: hazard (precipitation)
- Flooding risk: Western, southern Taiwan

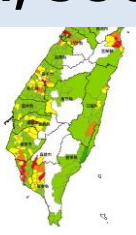
GFDL-ESM2G 

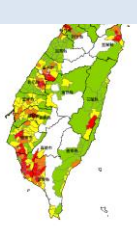
GFDL-E 

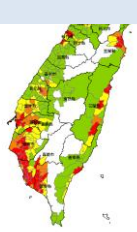


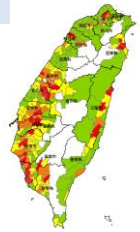




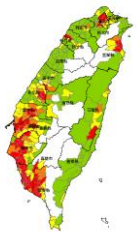






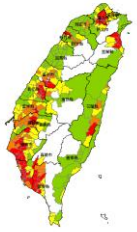
PSL-CM5B-LR 

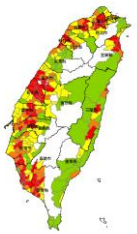
MIROC-ESM-CHEM 

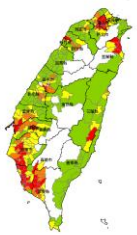
MIROC-ESM 

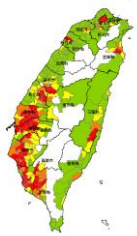
MIROC5 

MPI-ESM-LR 

MPI-ESM-MR 

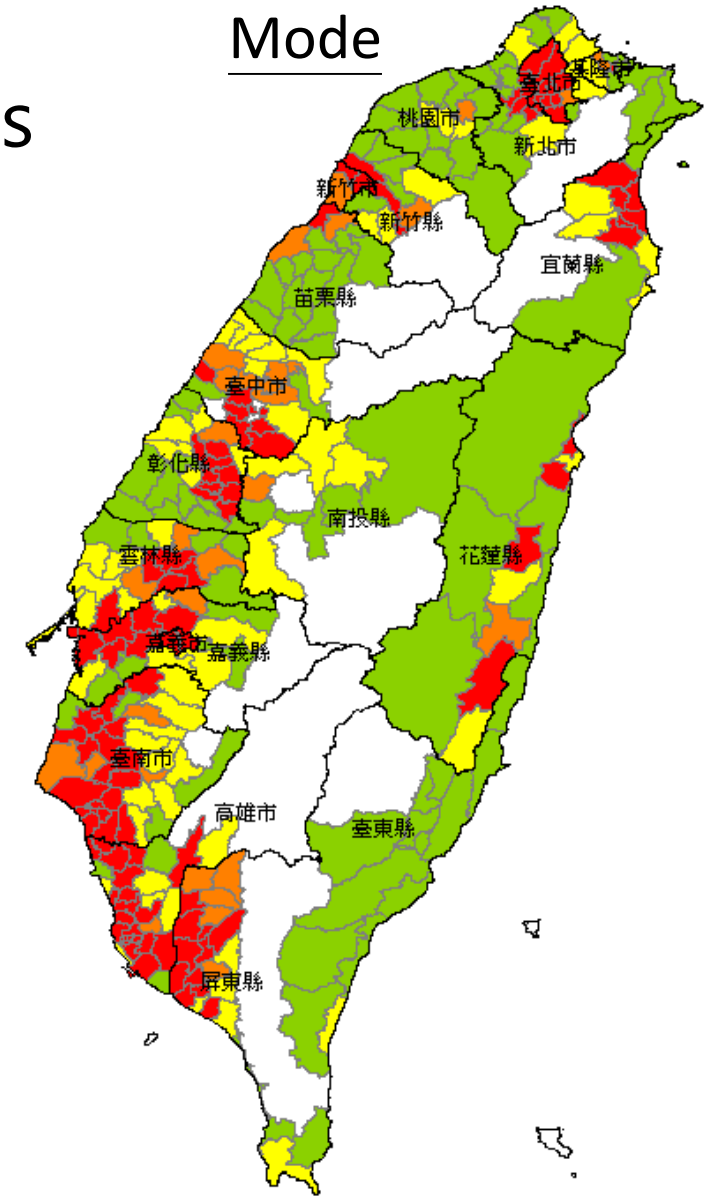
MRI-CGCM3 

MRI-ESM1 

NorESM1-M 

Mode of Risk level from Multi-GCM

- Mode map of risk level from most of GCMs in the future is higher reliability.
- There are 114 townships in level 5.(about 36%)
- Most are level 5, level 2



	Number of Township
Level 1	0
Level 2	103
Level 3	66
Level 4	31
Level 5	114
total	314

Uncertainty of risk map
(GCM consistency)

Uncertainty discussion

There are many methods to quantifying uncertainty.

①Mean and standard deviation

② Consistent of parameter change between GCMs

③Different percentile to show parameter change

① Mean and Standard Deviation of Temperature

- Using mean and 2 standard deviation of local temperature to show uncertainty GCMs

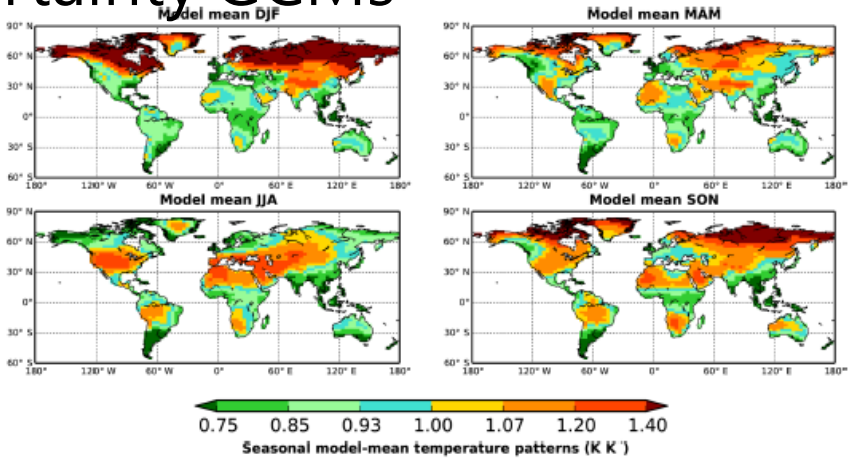
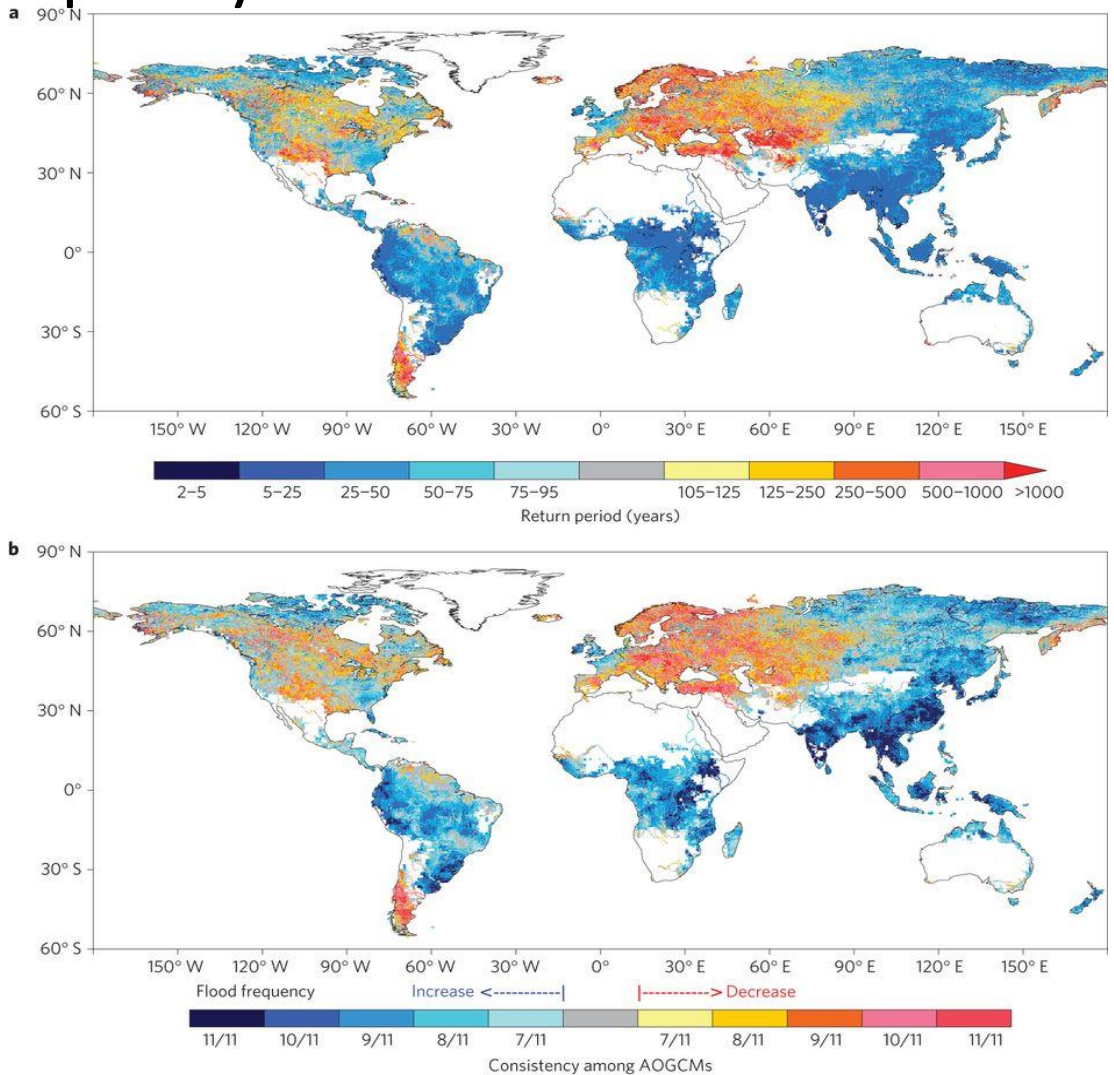


Figure 4. Seasonal means and variation (2 × SD) of the monthly patterns of local temperature change per degree warming over all land ($K K^{-1}$), across 22 GCMs. DJF is December, January and February; MAM is March, April and May; JJA is June, July and August; and SON

②Flood frequency

- Using number of models to show consistent of change of flood frequency



③ Change of Streamflow

- Using 95%、5% and median to show change of streamflow.

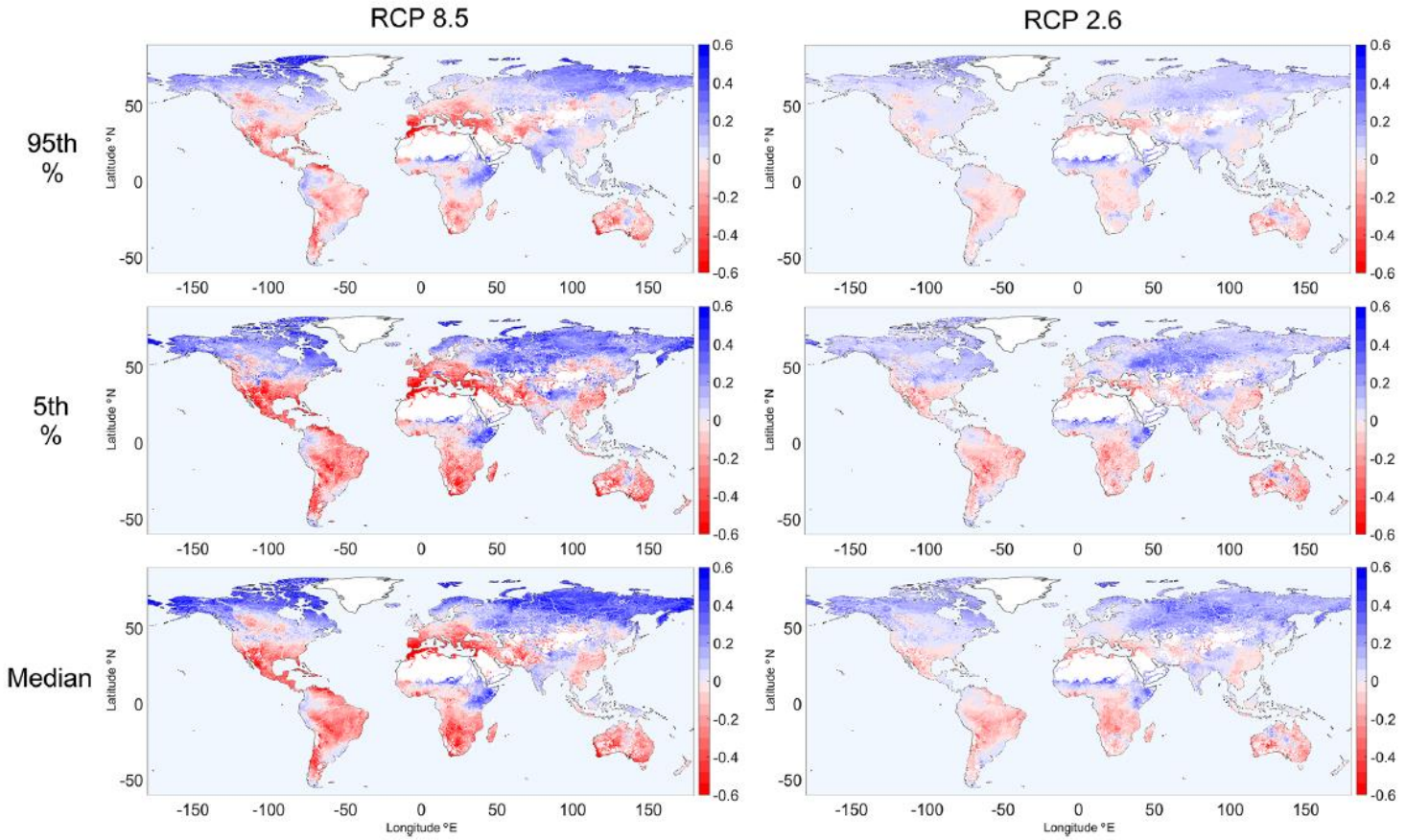
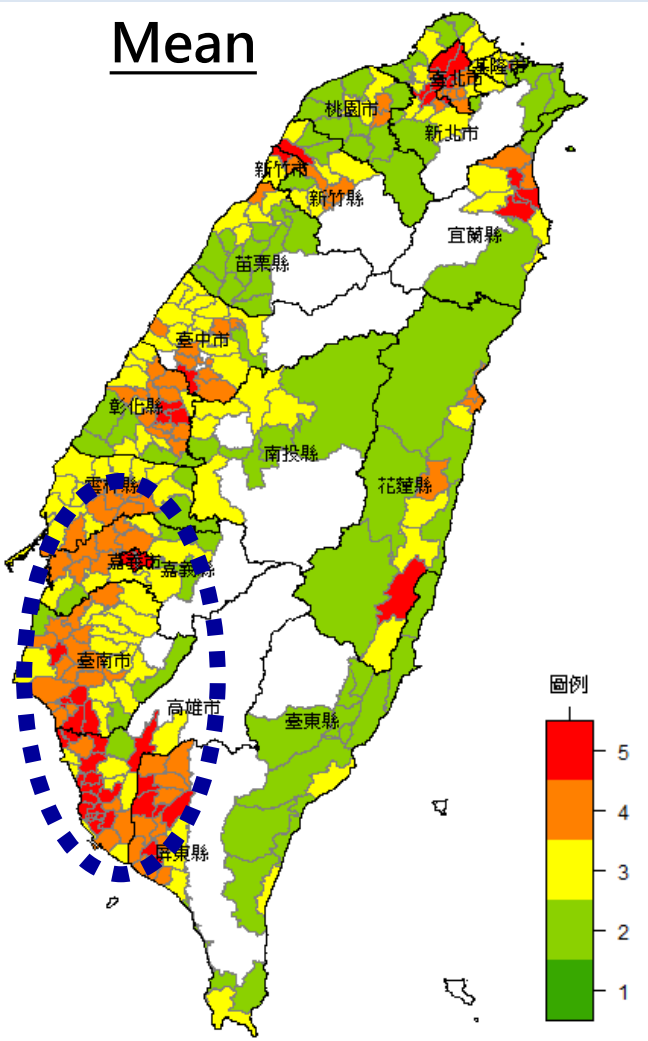
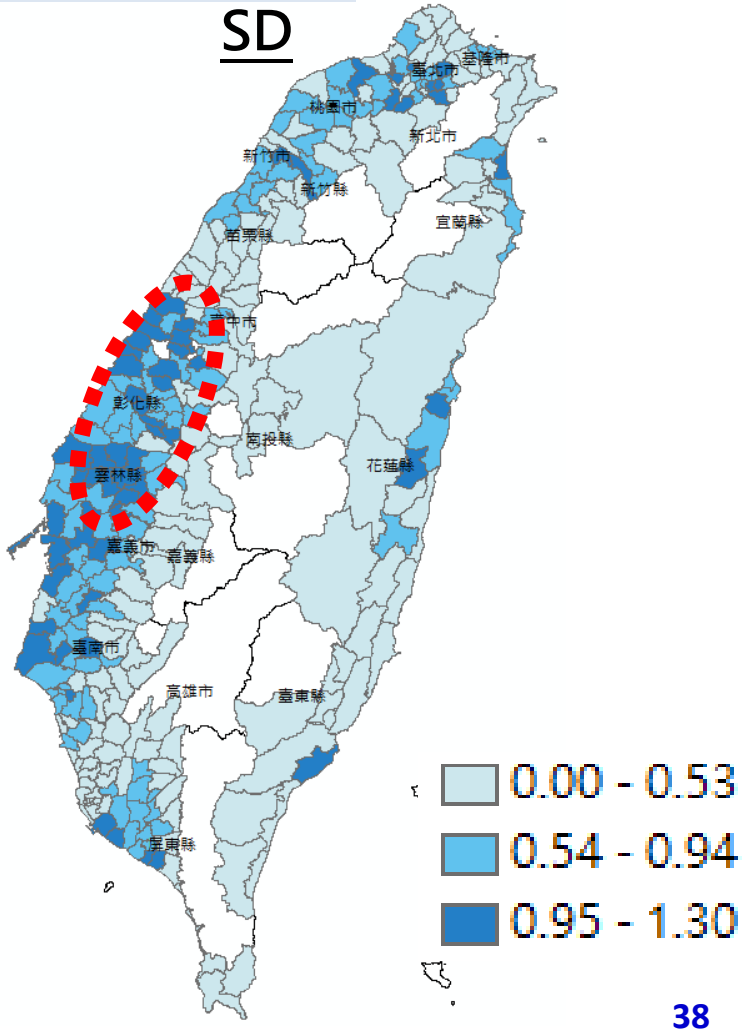


Figure 1. Global maps of normalized change in different streamflow percentiles (95th, 5th and median) under the RCP8.5 and RCI scenarios. Maps show the ensemble mean results of all 25 models.

Mean and Standard Deviation of Risk

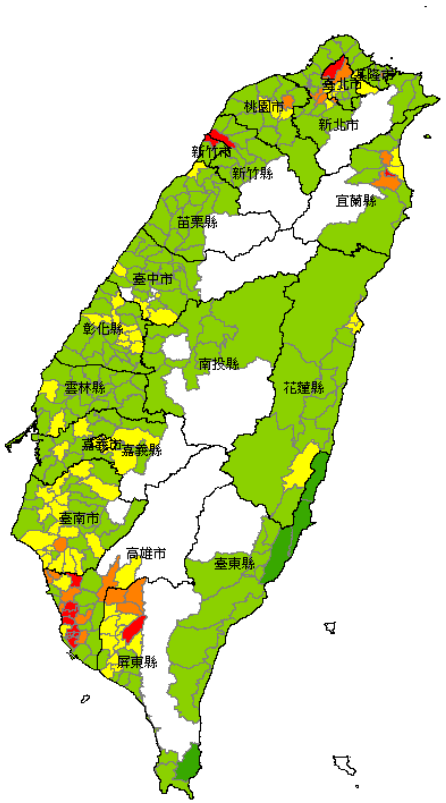
- High flood risk: Western, southern Taiwan
- High standard deviation: Central Taiwan





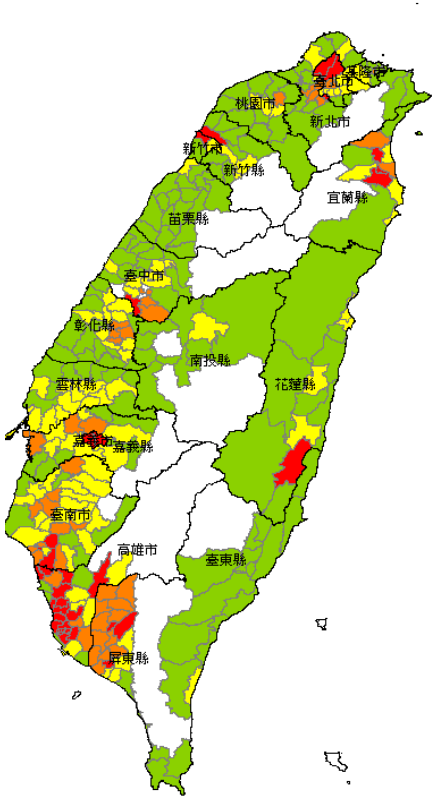
Different Percentile of Risk Level

95%



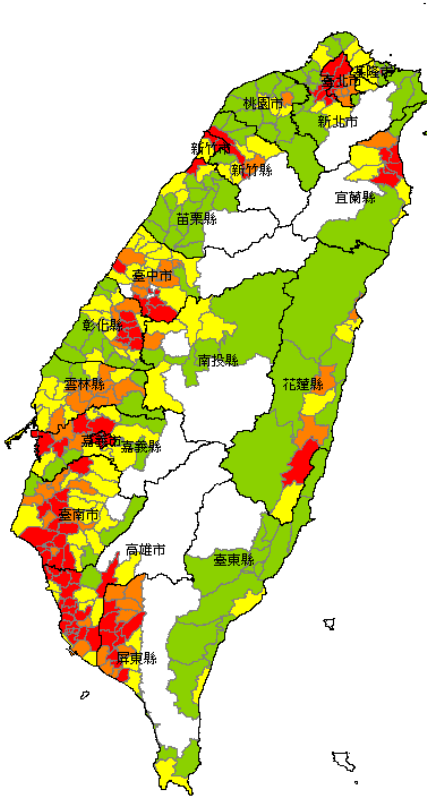
Very likely

75%



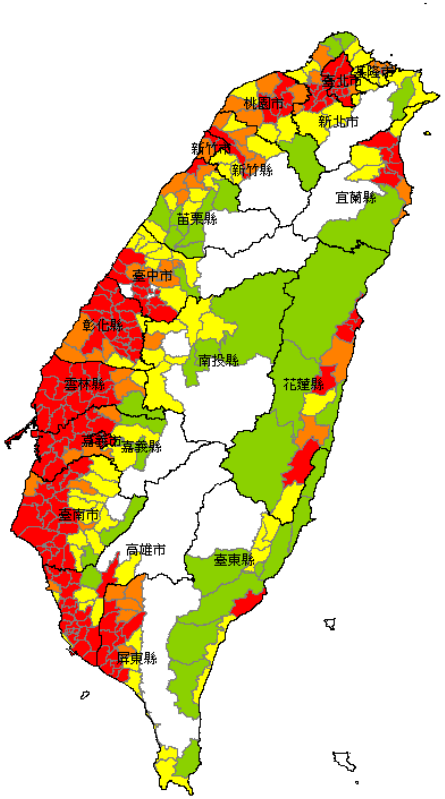
Likely

50%



About as likely as not

5%



Unlikely

Model Reliability

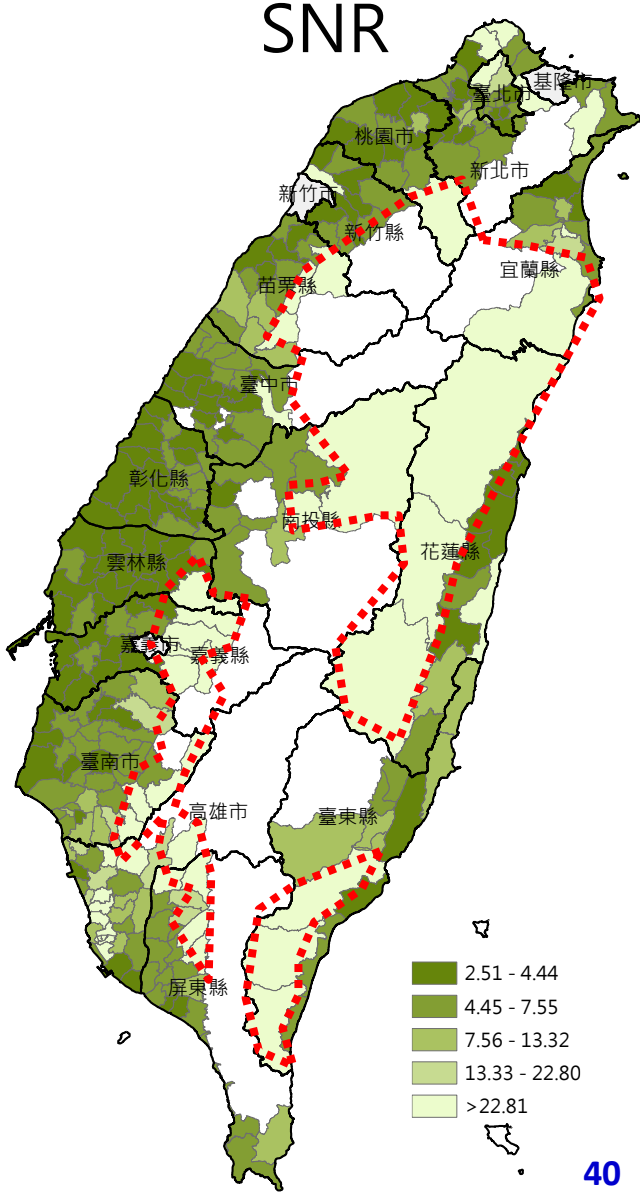
- Signal-to-noise ratio (SNR)

$$SNR = M/\sigma$$ (Chen et. al.,2014)

M: Ensemble mean of model

σ: Standard deviation of models

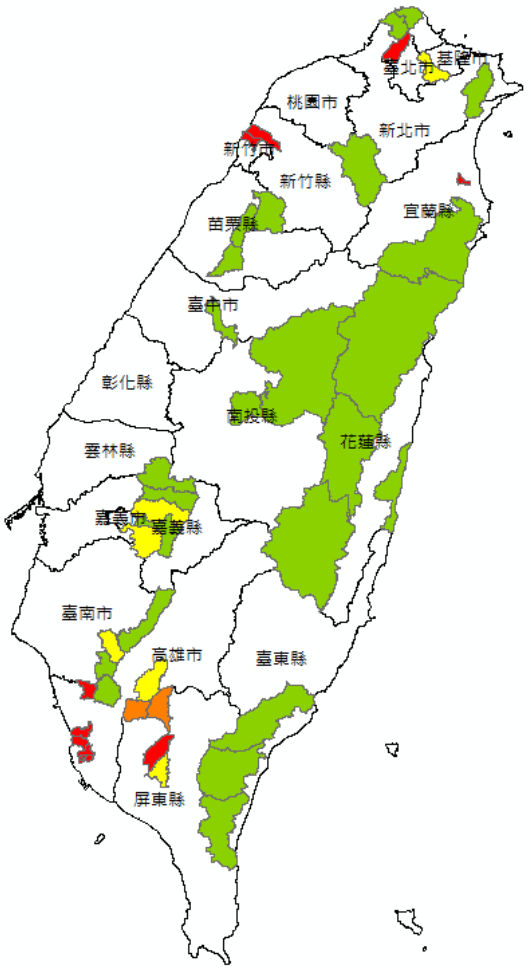
- The larger SNR value indicates that model of GCM is more consistent. For the risk index, it means higher reliability.

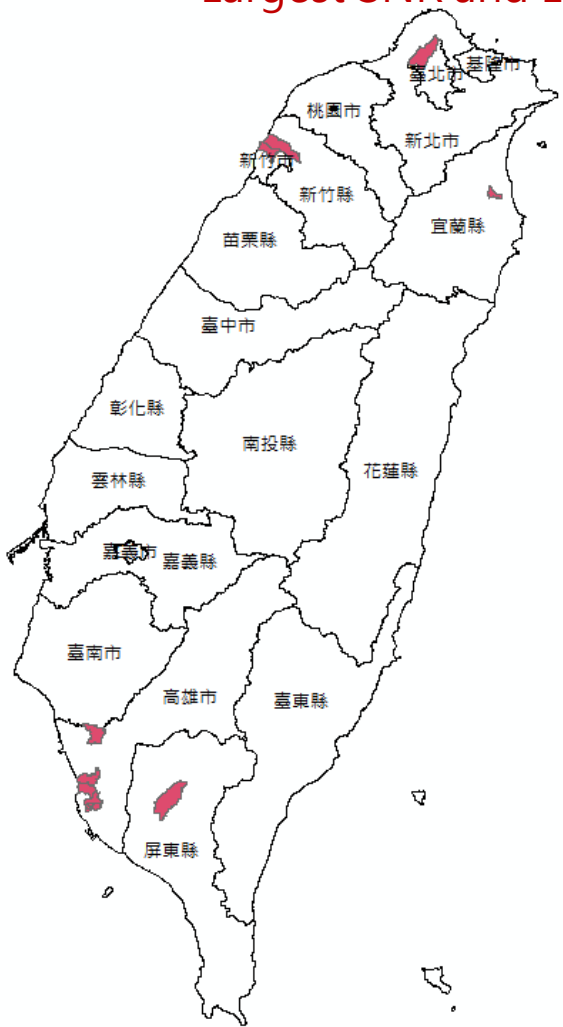


Township of Higher Reliability

- SNR values are largest in 44 townships, they are more consistent of GCMs and higher reliability. Moreover, 12 townships are level 5 of risk.

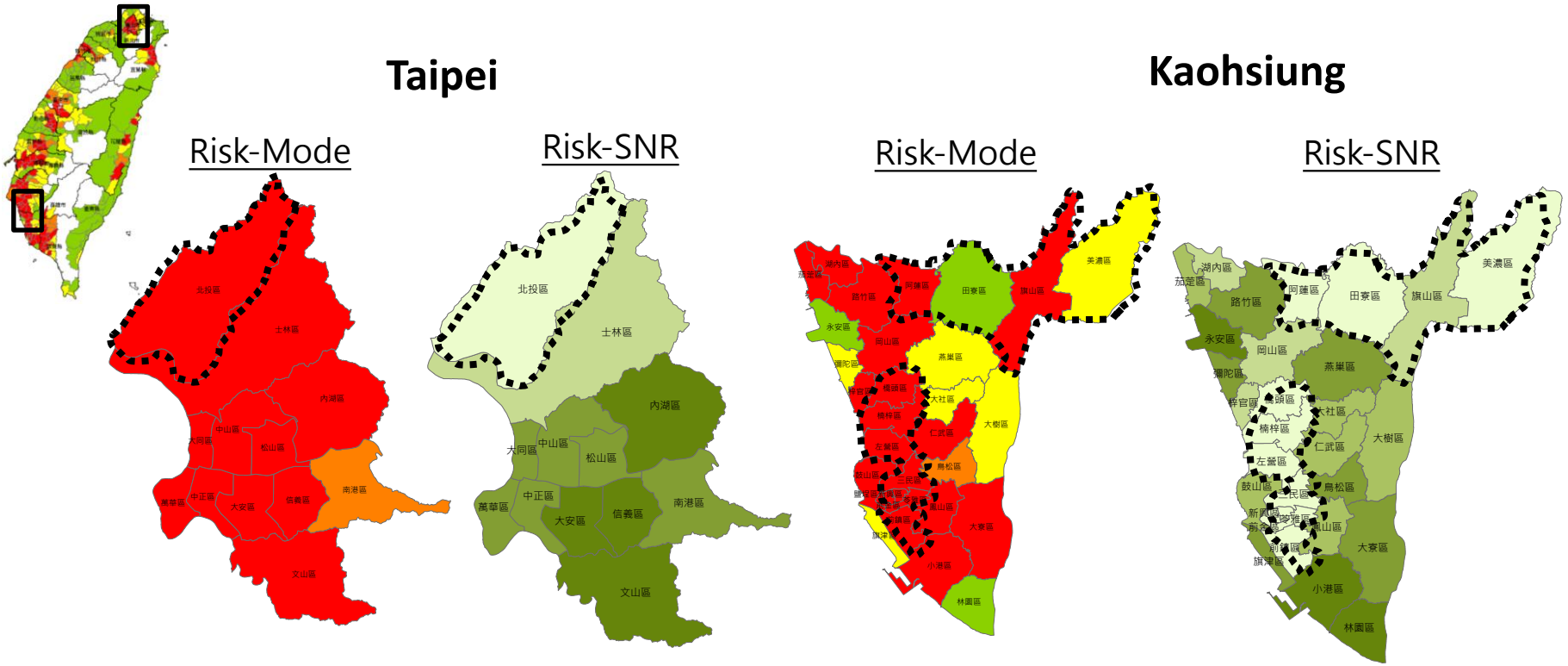
Largest SNR and Level 5





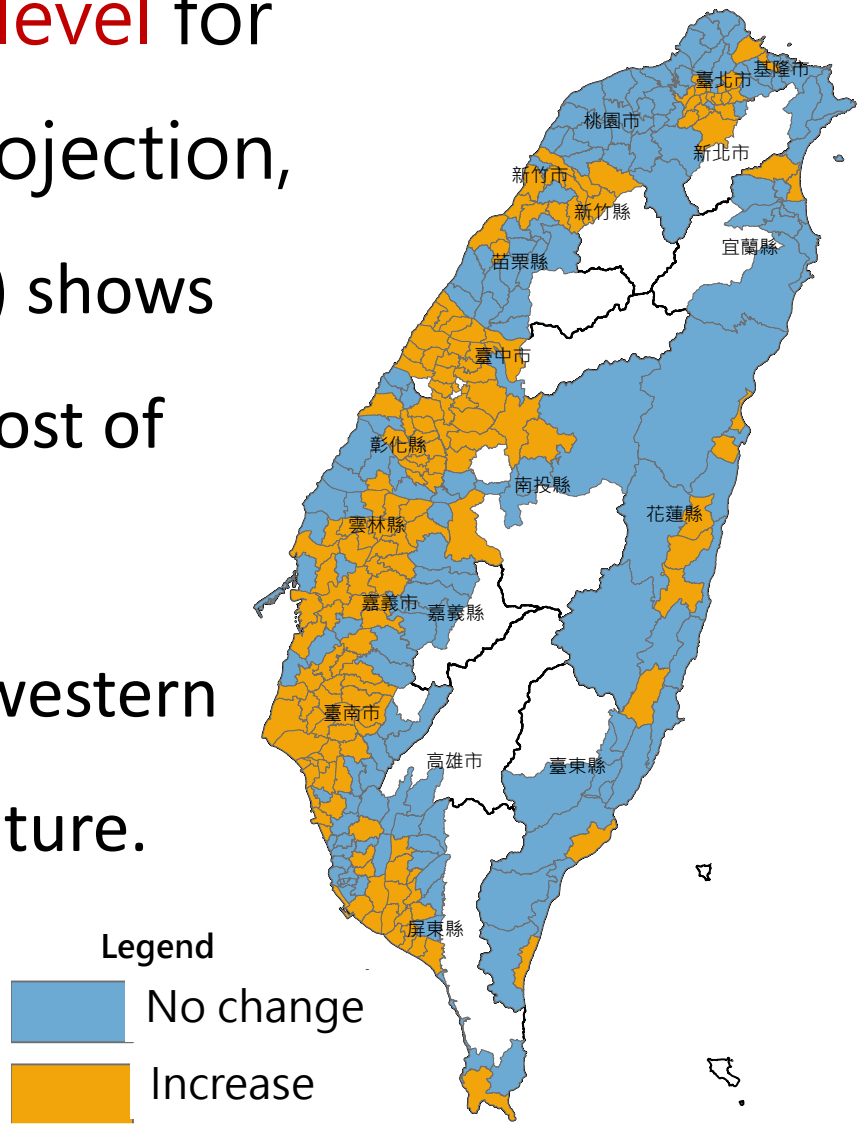
Flood Risk in Kaohsiung and Taipei

- Decision makers have to pay attention in townships for high risk level and high reliability of model.



Change of Future Risk Level

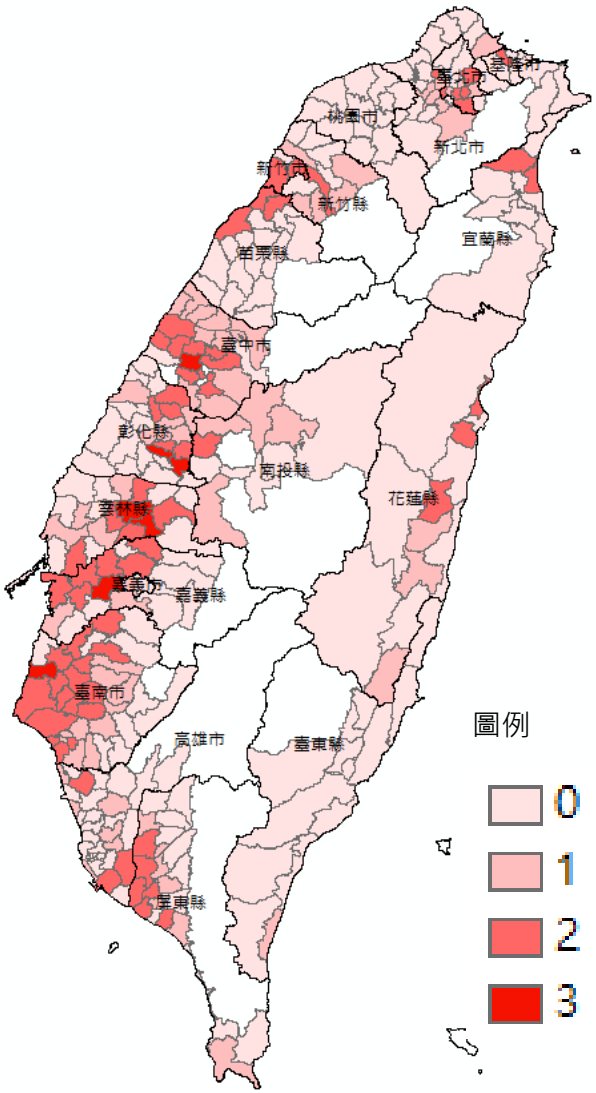
- Compared change of risk level for observation and future projection,
- Over 18 GCMs(high reliability) shows the risk level is the same in most of townships.
- The risk level will increase in western and southern Taiwan in the future.



Change of Risk Level

- Most GCMs show the risk is the same in most townships(166) in the present and future.
- The risk will increase three grades in 7 townships, and increase two grades in 70 townships.

Mode



County	Town
Pingtung	Xinyuan Township
Miaoli	Yuanli Town
Taoyuan	Zhongmu District
Taoyuan	Daxi District
Kaohsiung	Kaohsiung City
Taichung	Taichung District
Tainan	Baihe District

Concluding Remark

- High risk area：
  - Enhancing flood control adaptation strategies in coastal towns of south Taiwan in the middle of the 21st century.
  - There are 114 townships in risk level 5.(about 36%)
  - The risk will increase three grades in 7 townships
  - National land-use planning should be consider flood impact in the hot spot area (southern Taiwan).

Concluding Remark

- Uncertainty of GCM
  - Signal-to-noise ratio and standard deviation can assess consistent of risk level from GCMs
  - Decision makers have to pay attention in higher reliability and high risk townships(12).

- Application of risk map :
  - Decision maker can consider the uncertainty of risk map and evaluate suitable adaptation strategies in hot spot area.

Future Work

- To analyze more scenarios
  - RCP2.6、RCP4.5、RCP6.0、1.5℃、2 ℃
- Using risk maps to different spatial scales (grid、multi-unit of population)
- Evaluated environment change(landuse) in the future.
- Applied risk map of county scale to national land plan.

Thank YOU for your attention!