

CMIP6多模式統計降尺度資料產製與技術研發

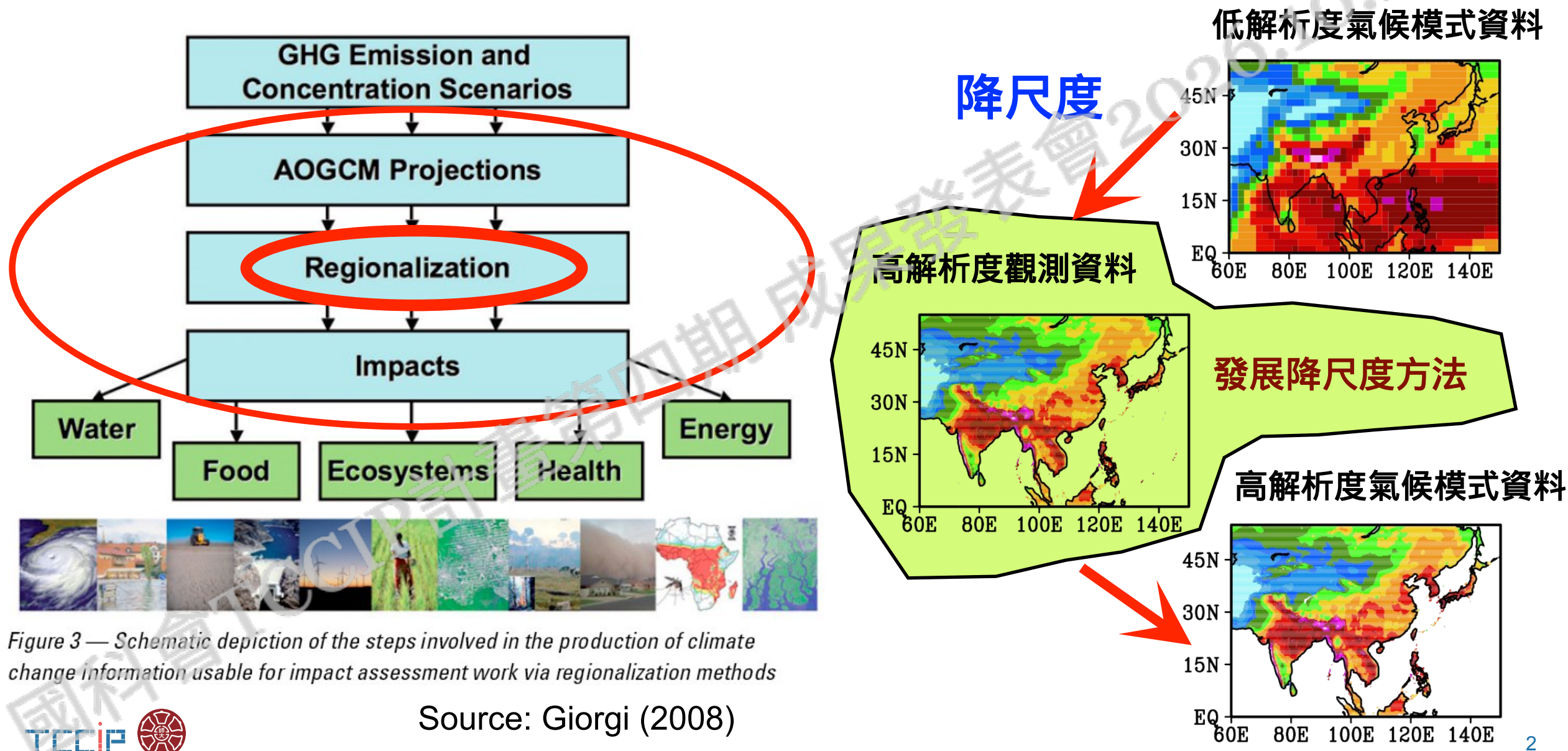
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Chen, C.-T., Y.-S. Tung, C.-Y. Wang, and S.-L. Lin, 2026: Assessing Taiwan's Future Climate: High Resolution Projections and Regional Impacts From Statistical Downscaling of CMIP6 Data, International Journal of Climatology, e70431 <https://doi.org/10.1002/joc.70431>



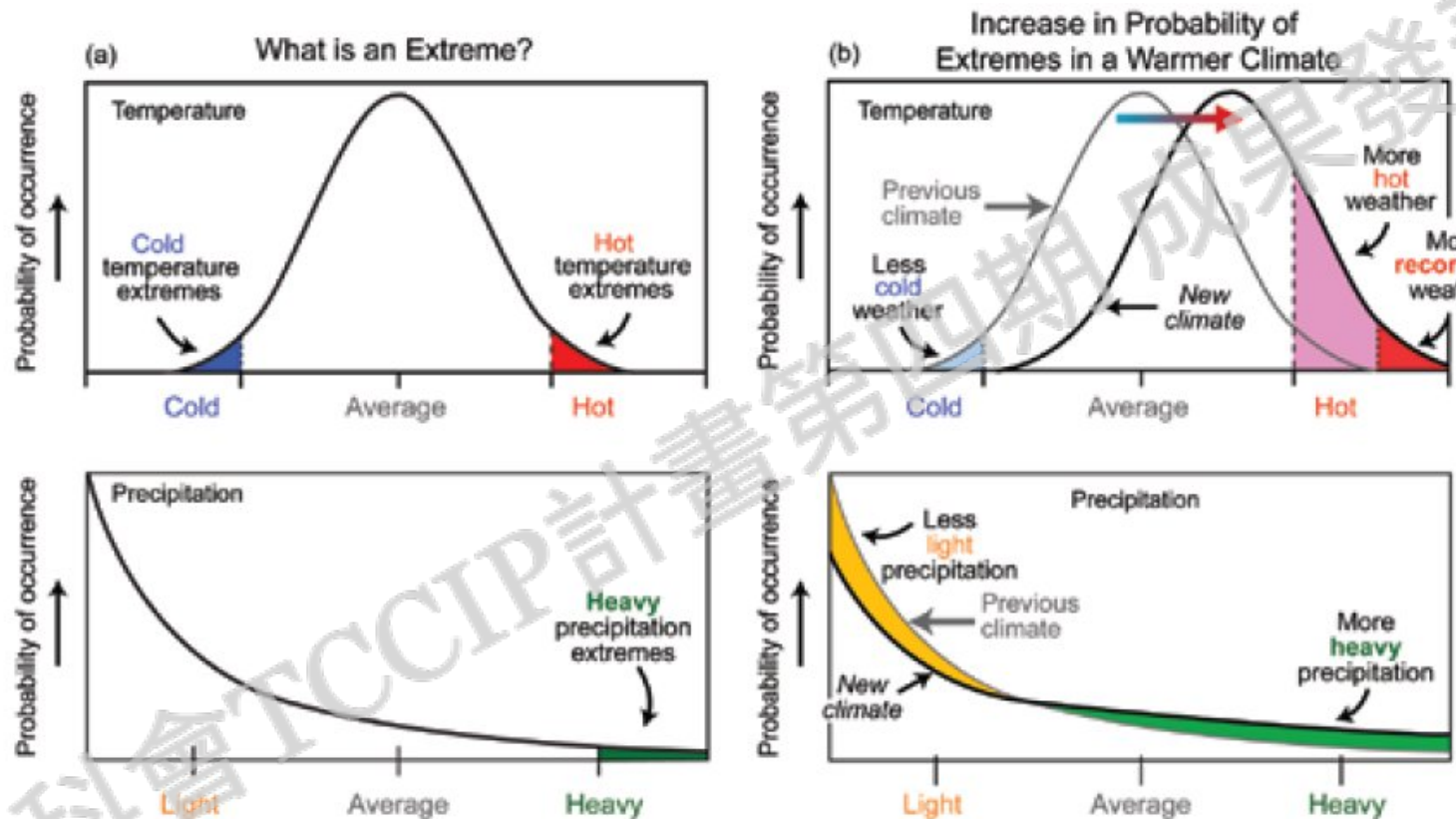
氣候變遷推估資料為什麼需要降尺度？



極端天氣氣候的降尺度

Need high-impact and high-resolution climate information for:

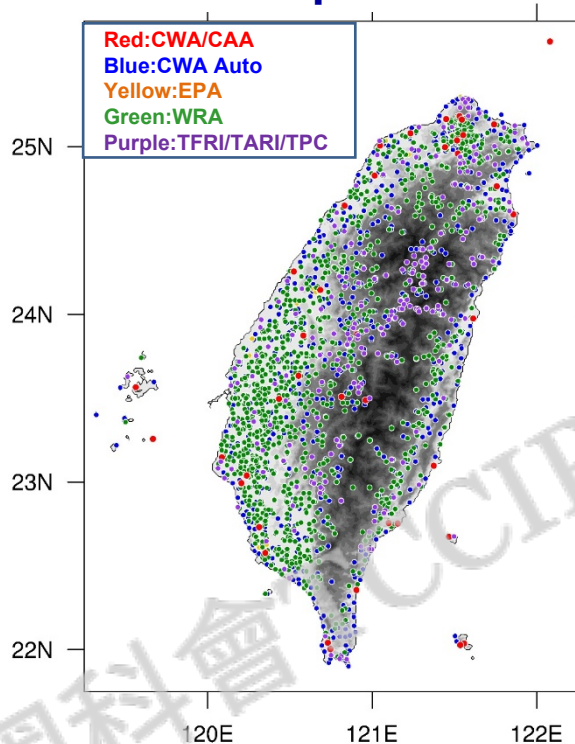
- assessing environmental and societal relevant climate change impacts
- developing adaptation strategies and mitigation efforts



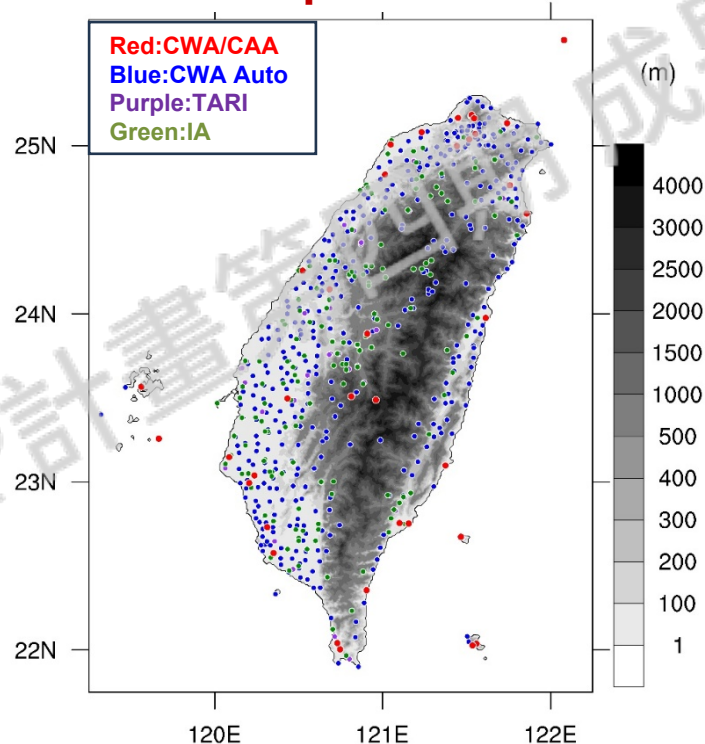
TCCIP 計畫的高解析度網格化觀測資料

- Precipitation and Temperature (Tmax, Tavg, Tmin)
- 1km and 5km spacial resolution
- 1960~2024 (65 years) daily data(continuously updated)

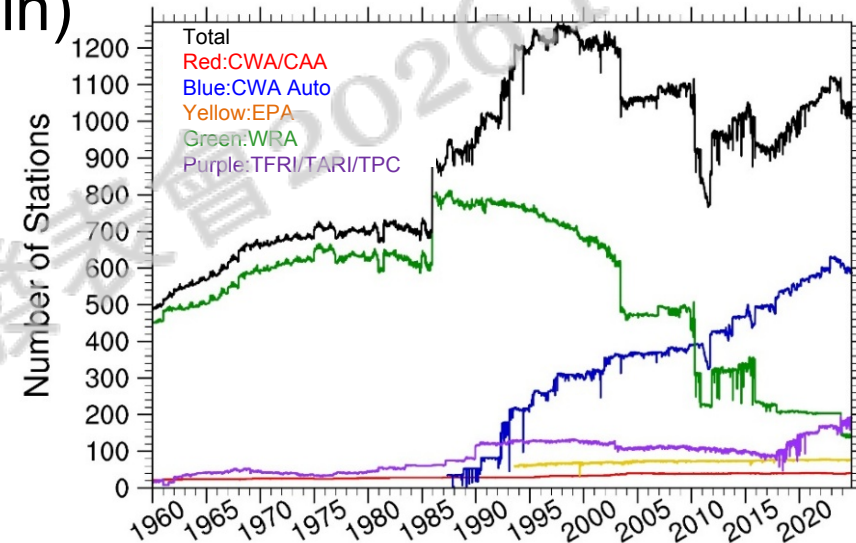
Precipitation



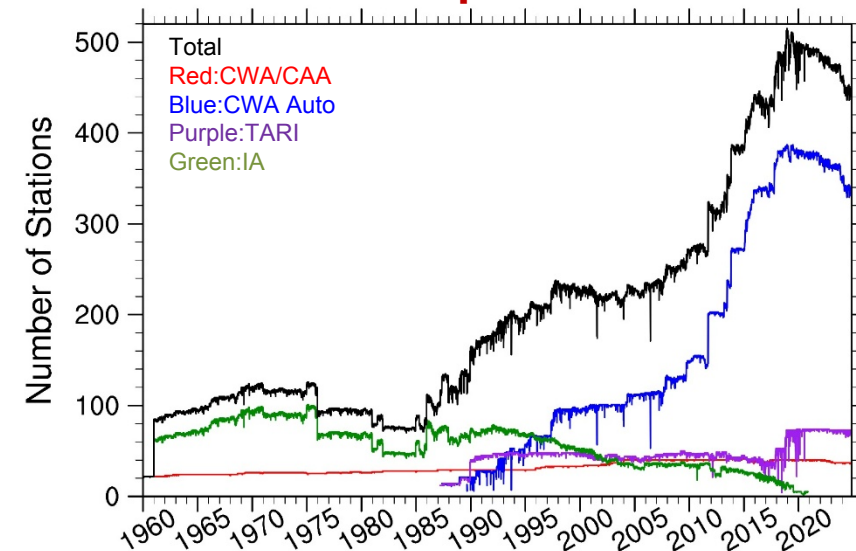
Temperature



Precipitation

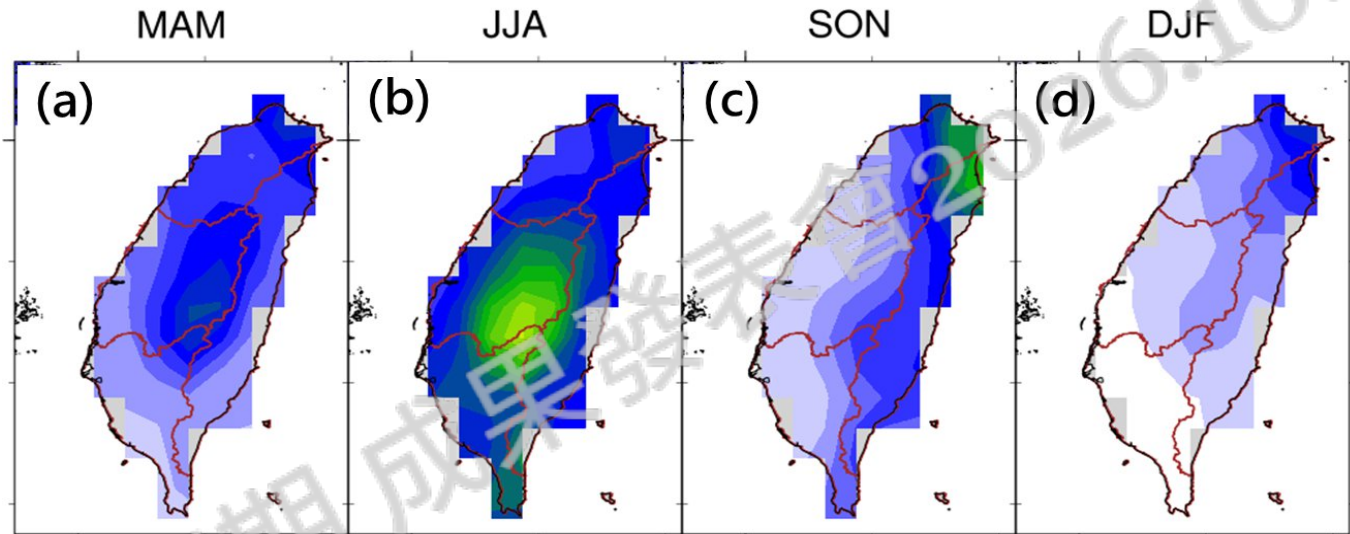


Temperature

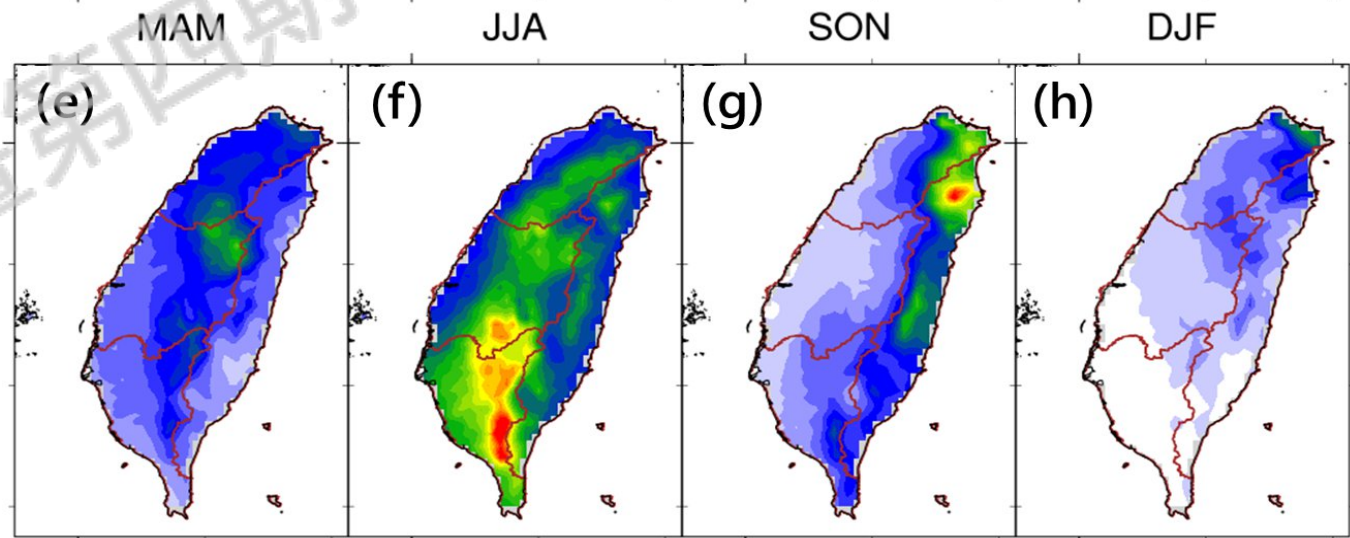


提高觀測資料解析度以獲得區域細節

APHRODITE
(25km)



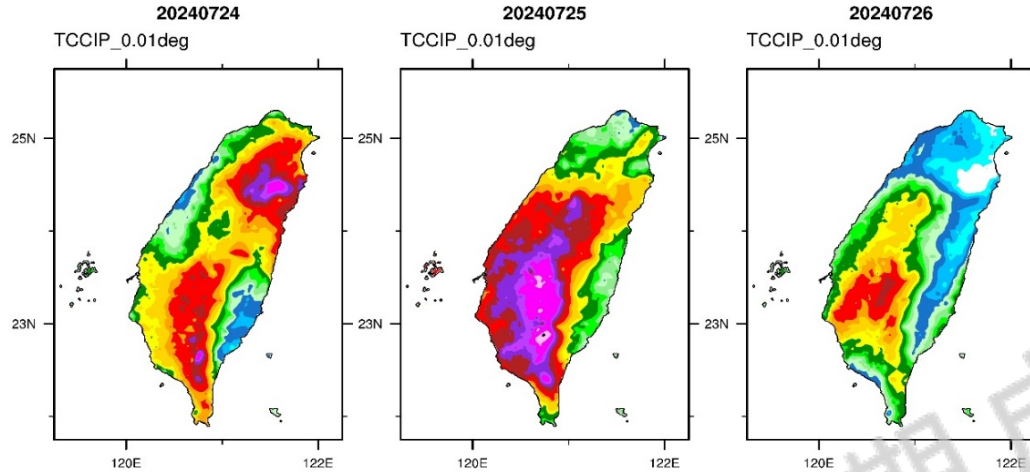
TCCIP_PR
(5km)



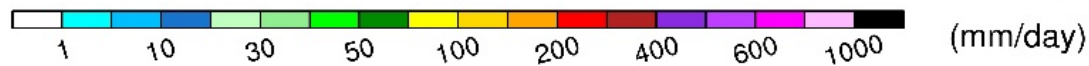
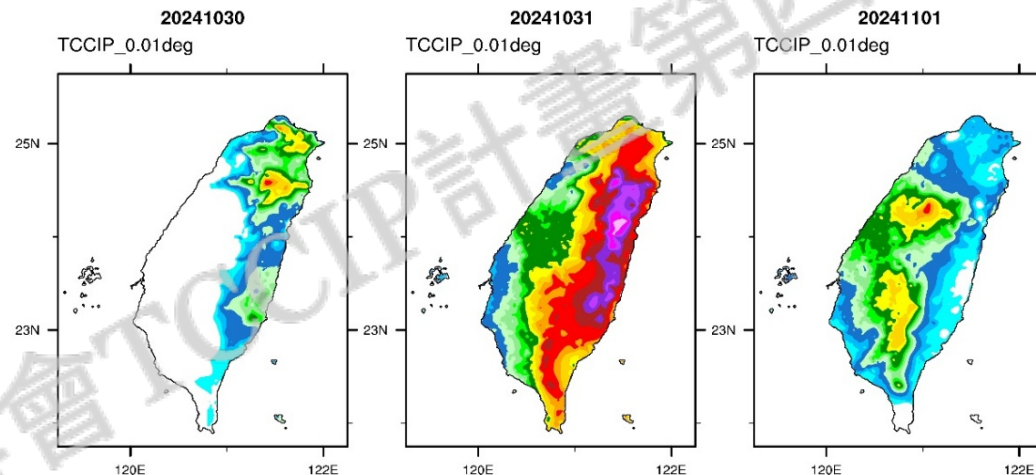
網格觀測資料中的極端事件（舉例說明）

➤ Rainfall

凱米 GAEMI[07/24~07/26]



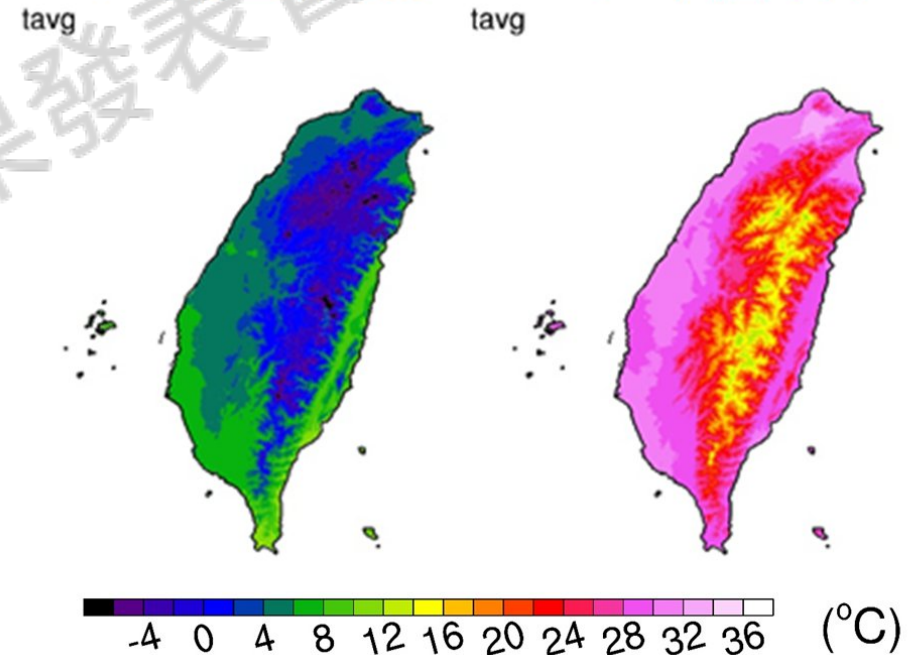
康芮 KONG-REY[10/30~11/01]



➤ Temperature

2016 Sever Cold Wave

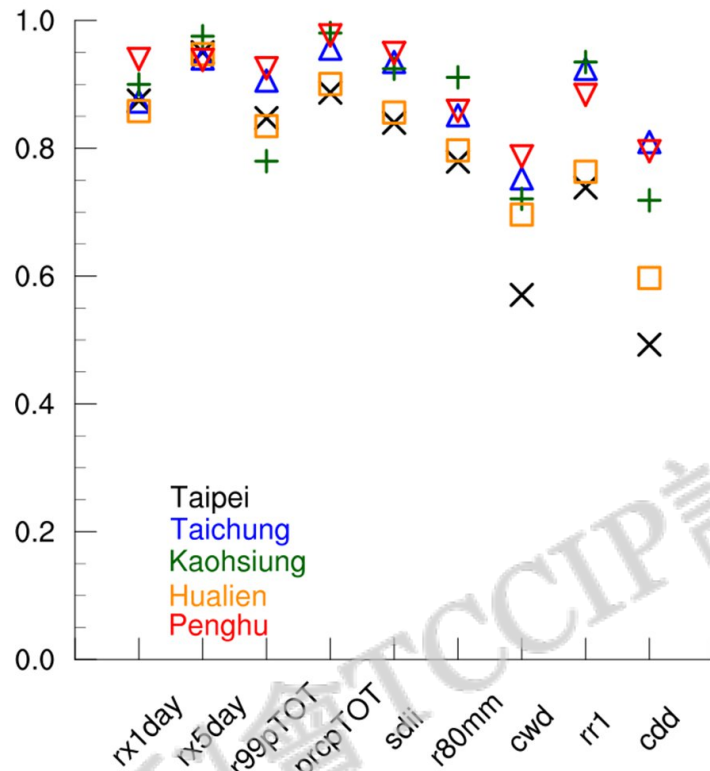
2017 Heat Wave



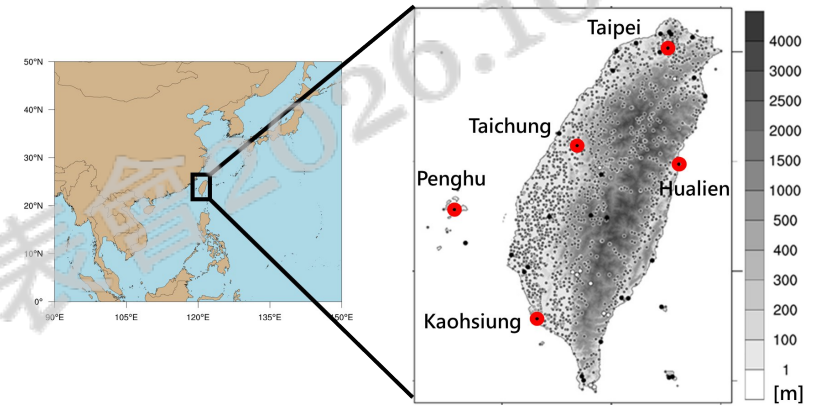
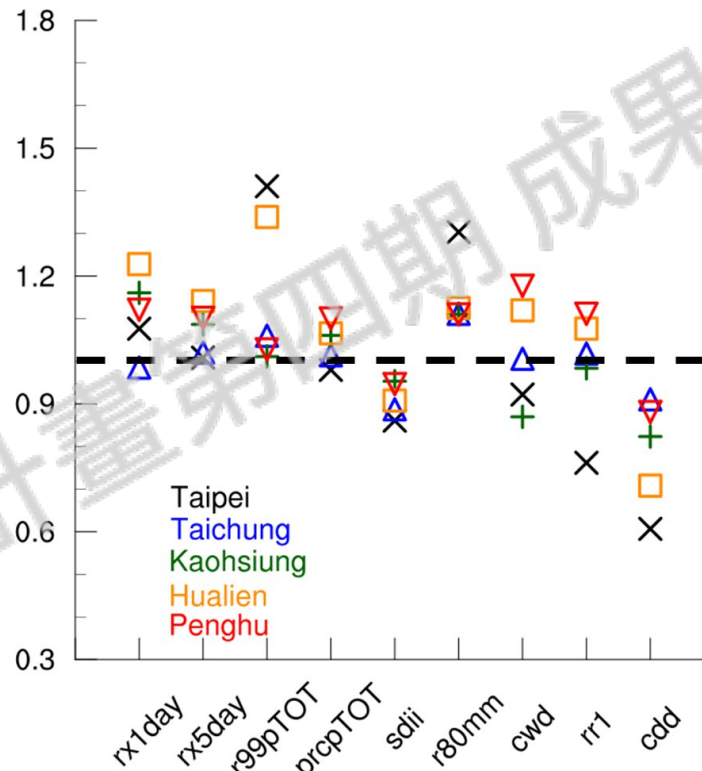
以測站資料驗證網格資料的極端天氣與氣候指標

- Large uncertainty over the southwest mountain in summer

(a) extreme indices corr. grids@STN



(b) extreme indices nor-rmse grids@STN



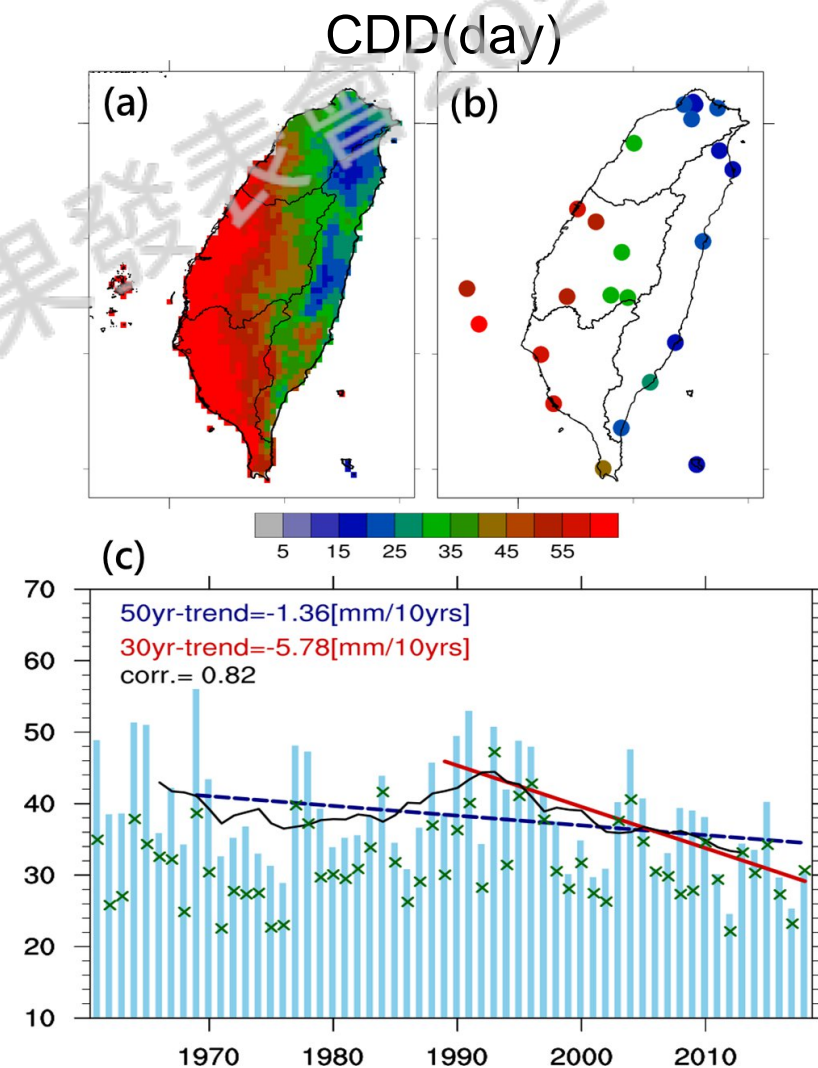
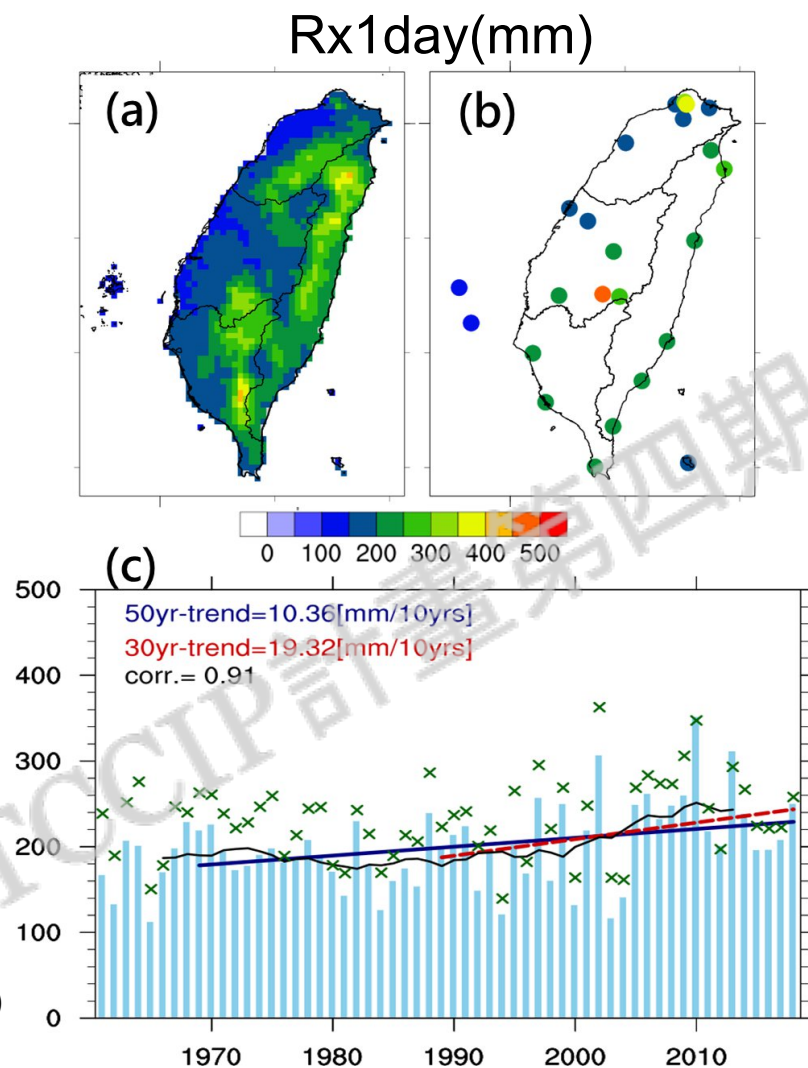
WMO-Extreme Climate Indices (ETCCDI)

Index	Full name
RX1day	Max 1-day precipitation amount
RX5day	Max 5-day precipitation amount
R80mm	Heavy precipitation days
RR1	Rainy days
CDD	Consecutive dry days
CWD	Consecutive wet days
R99pTOT	Annual total Precipitation when RR> 99p
PrcpTOT	Annual total precipitation in wet days
SDII	Simple precipitation intensity index

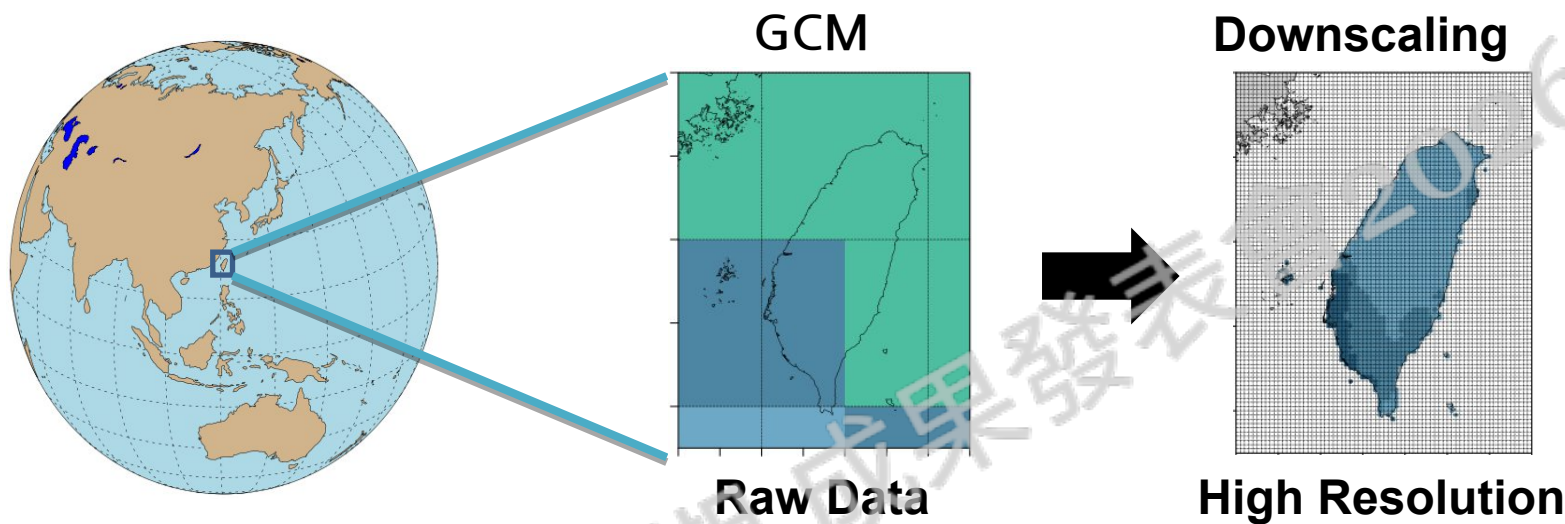
降雨極端指標的長期趨勢

➤ Extreme rainfall intensity increase

➤ Recent 30 year become drier



TCCIP 未來氣候推估降尺度資料有哪些？

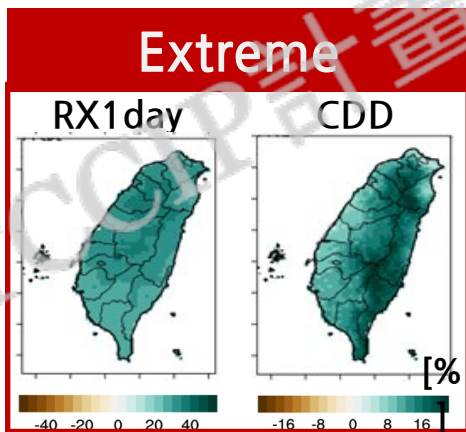
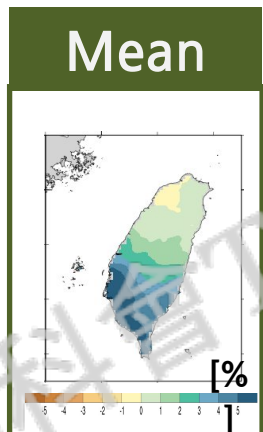
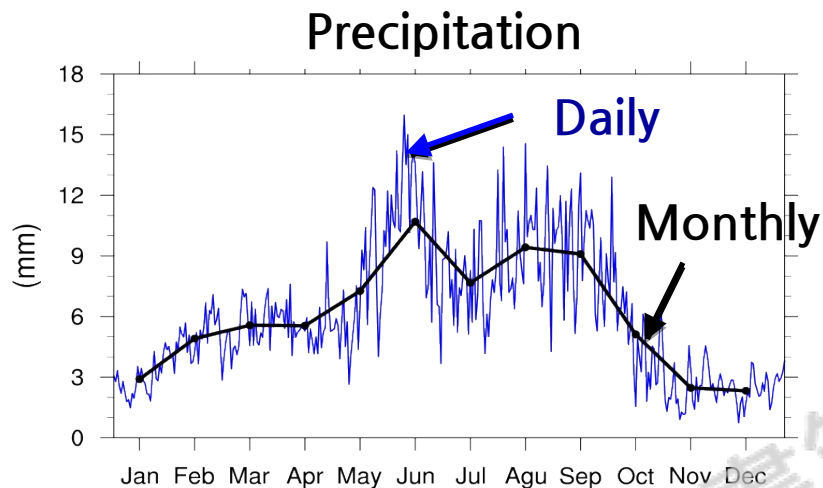


Dataset	Dynamical(DD)	Statistical(SD)
GCM (Raw Resolution)	MRI、HiRAM AMIP (25~60km)	CMIP6 ESMs (100~250km)
Produce resolution	1.2~3.5km	1km or 5km
Temporal	Hourly	Daily
Method	Physical Equation (Thermal and Dynamical)	Statistical Method Quantile Mapping(QM) Quantile Delta Mapping(QDM)
Produce time	Large computing resource	Simple, Fast
Application	Disaster events	Extreme climate

統計降尺度資料

- Daily data represented realistically extreme condition

- Follow international trend
- Construct the newest scenario dataset



2010

AR4

2014

AR5

2022

AR6

	TCCIP I、 II	TCCIP
Dataset	AR4 monthly data AR5 monthly data	AR5 daily data AR6 daily data Station location downscaling
Scenarios	20c3m、 A1B、 B1、 A2 RCP2.6、 4.5、 6.0、 8.5	RCP2.6、 4.5、 6.0、 8.5 SSP1-2.6、 2-4.5、 3-7.0、 5-8.5

統計降尺度所使用的CMIP6氣候模式與未來情境

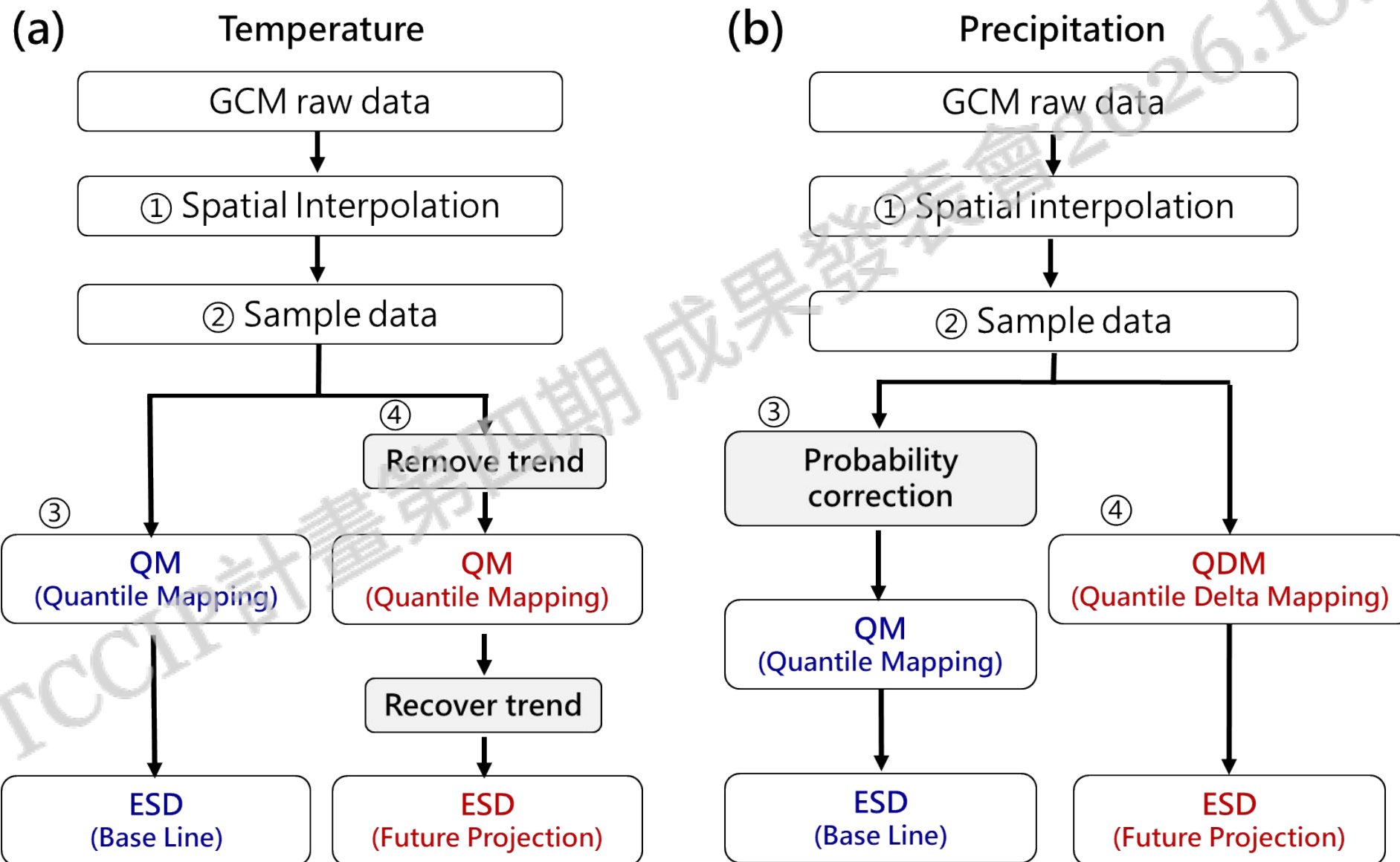


The number of GCMs:

	Historical	Future Projection(Tier 1)				Future Projection(Tier 2)		
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5	SSP1-1.9	SSP4-3.4	SSP4-6.0
Precipitation	31	28	29	27	29	9	5	5
Temperature	28	25	26	23	26	9	5	5

*Tier 2 provide the specific scenarios dataset

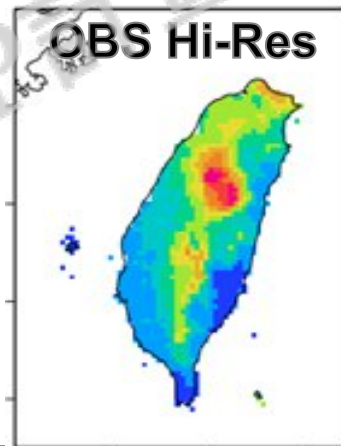
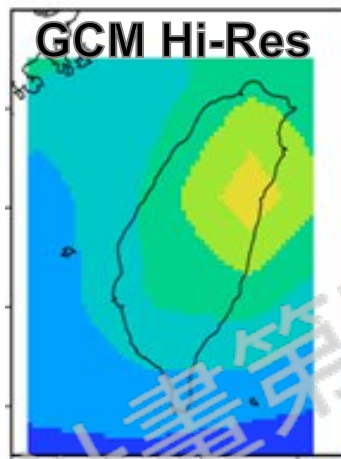
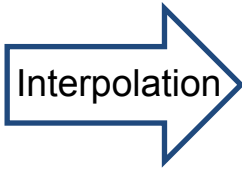
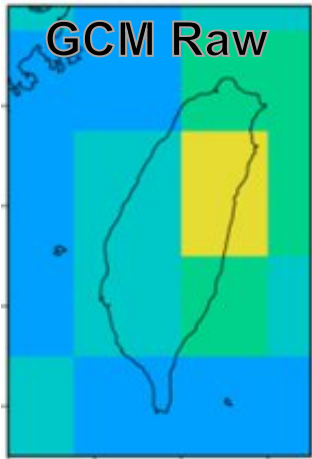
統計降尺度的流程



統計降尺度的方法與步驟

Step ① Interpolation

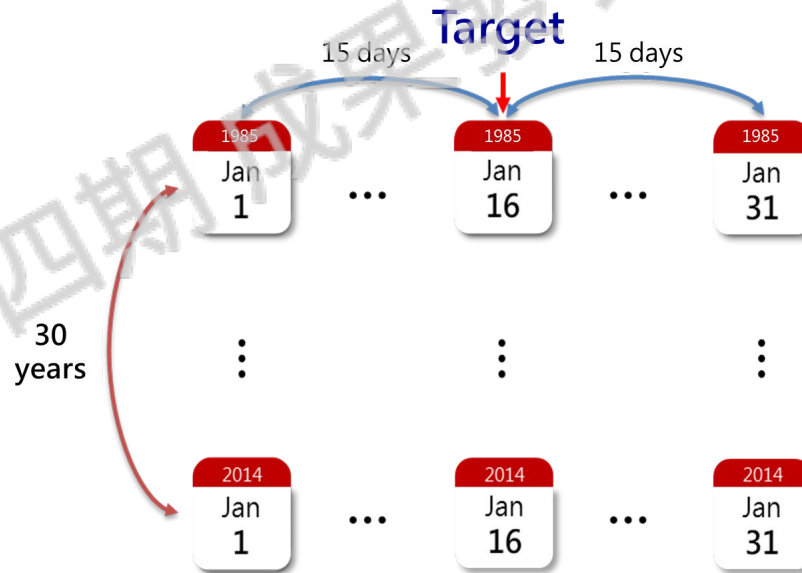
- Bilinear interpolation
- GCM raw resolution $\rightarrow 0.05^\circ$



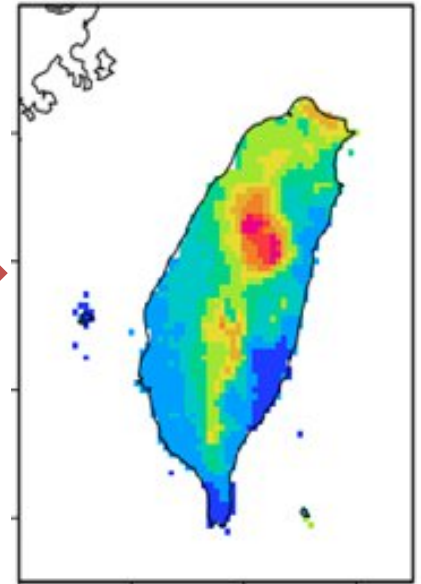
Step ②

Sample daily data

- Collect 30 days time window climatology data

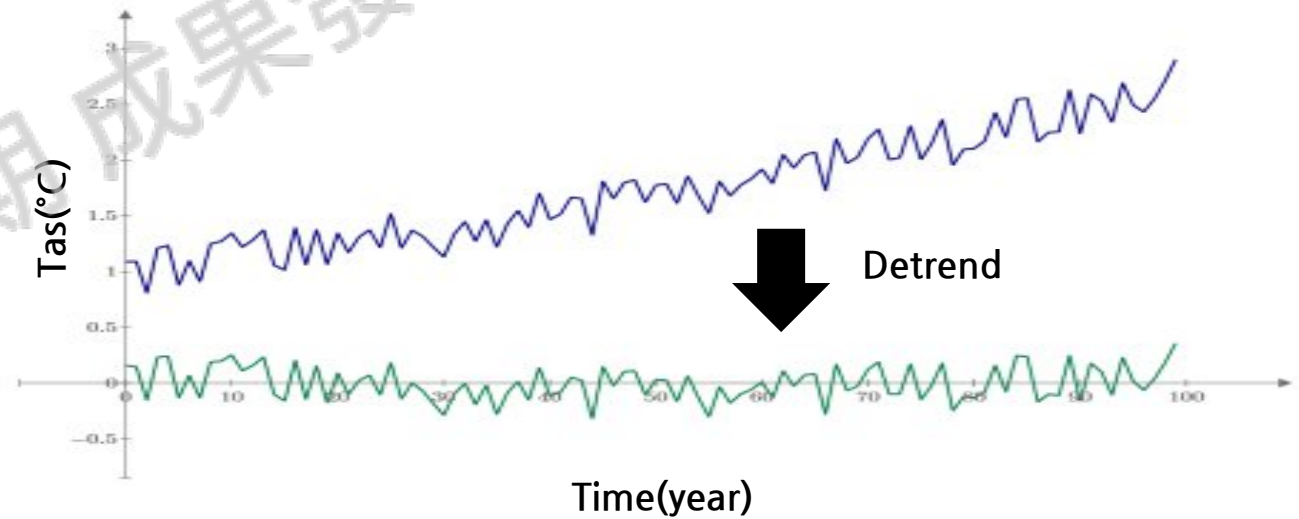
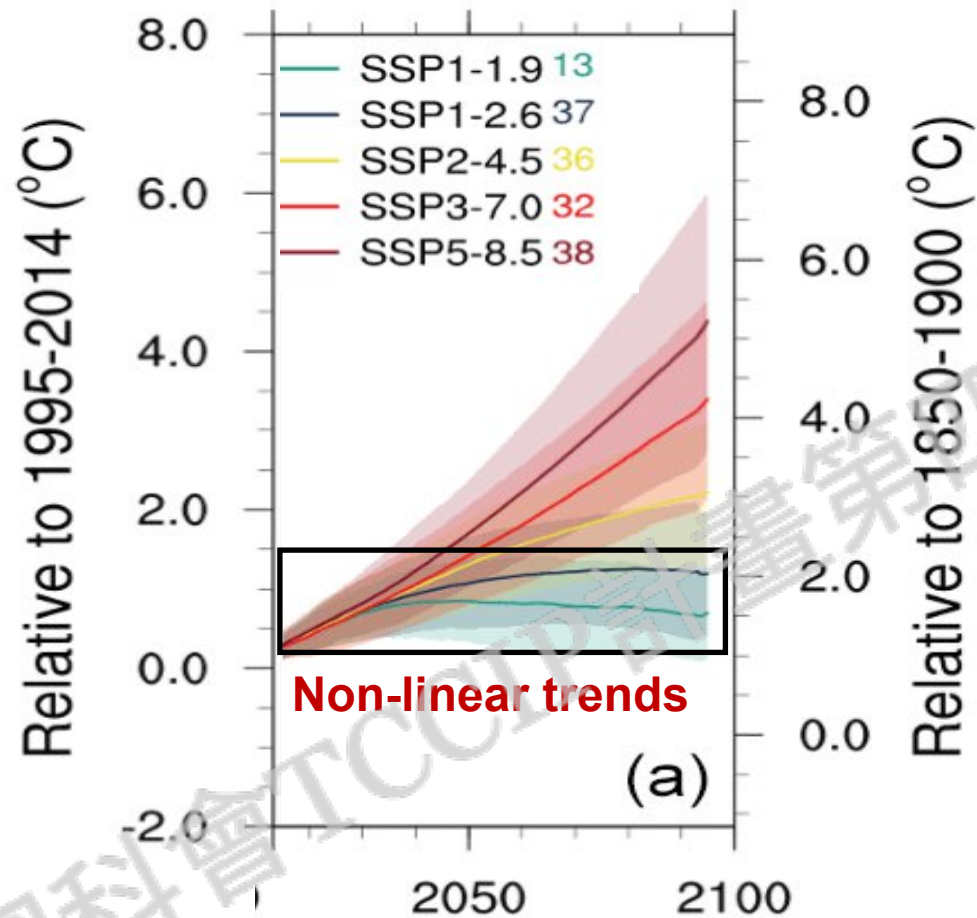


Downscaling data

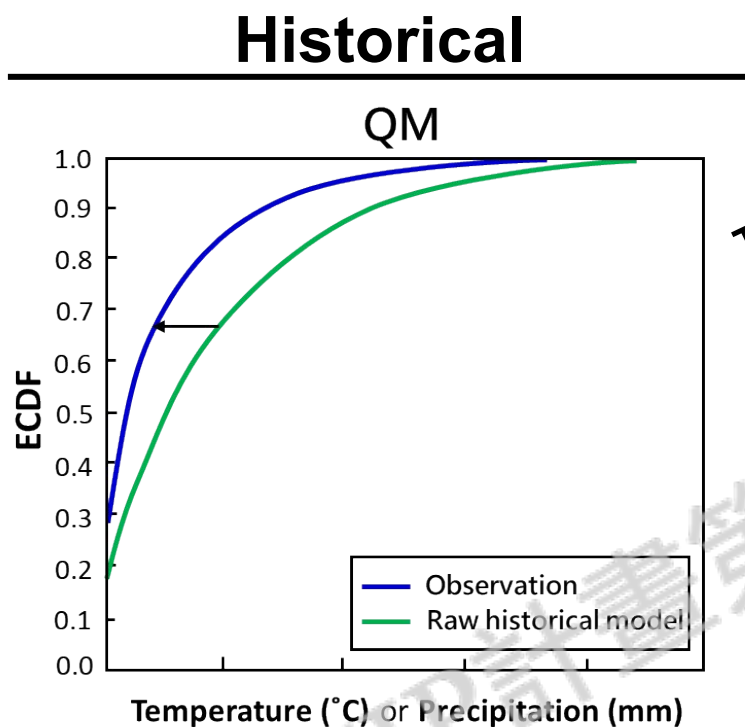


氣溫資料在進行統計降尺度前先移除長期趨勢

To fit the non-linear global warming scenario, detrend by polynomial function and then reconstruct the daily temperature data after bias correction

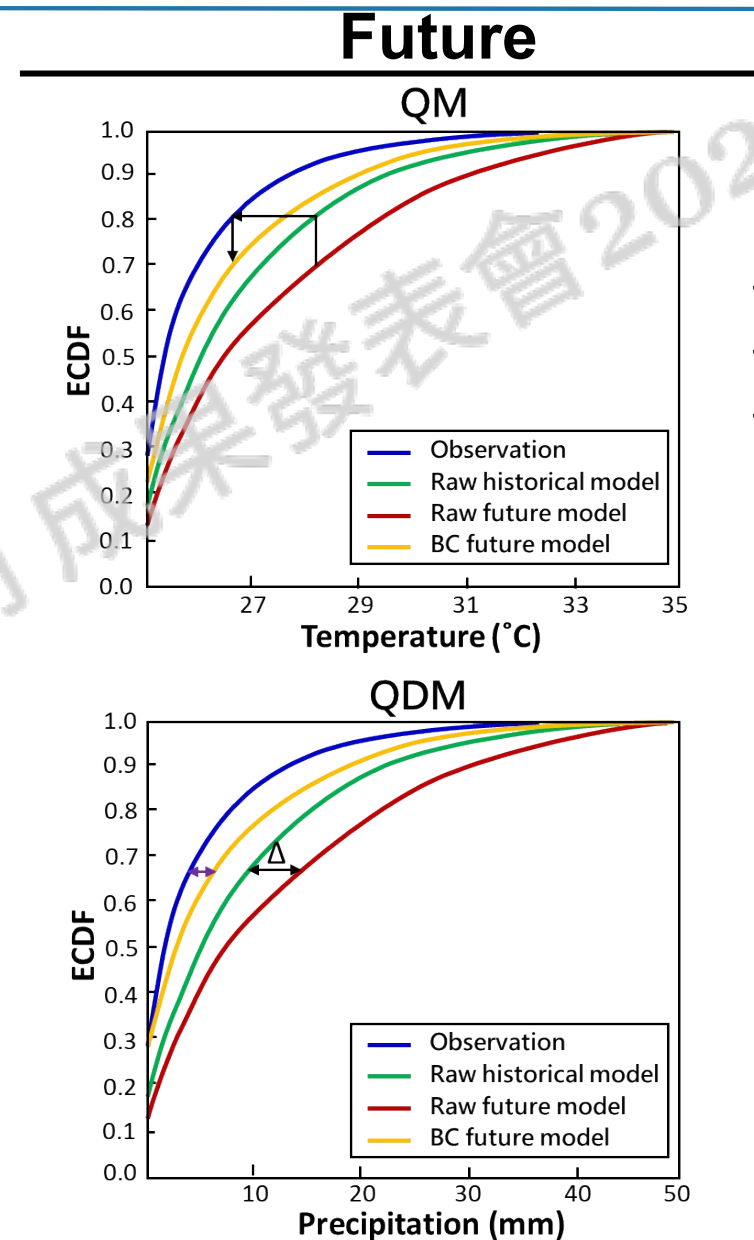


誤差修正方法的示意圖



Temperature

Precipitation



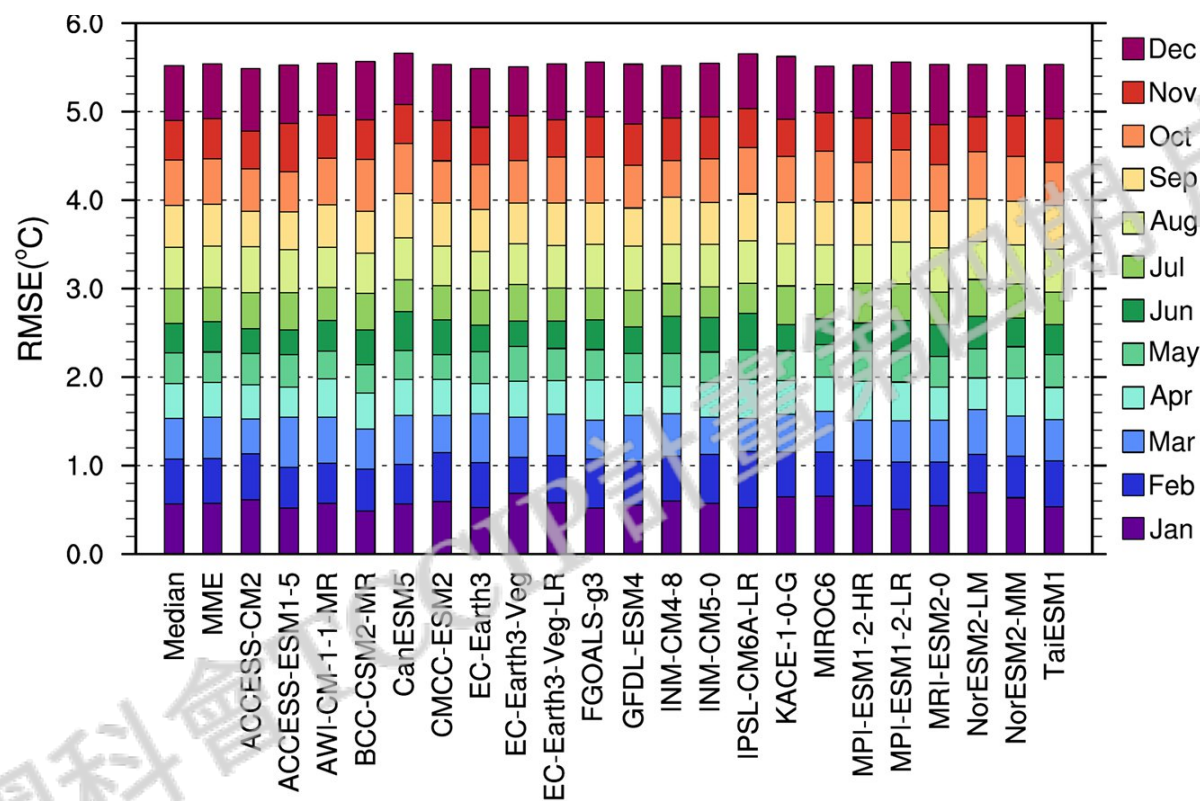
Keep GCM long-term temperature trend and corrected the fluctuation change

Downscaling data corrected by GCMs precipitation delta change

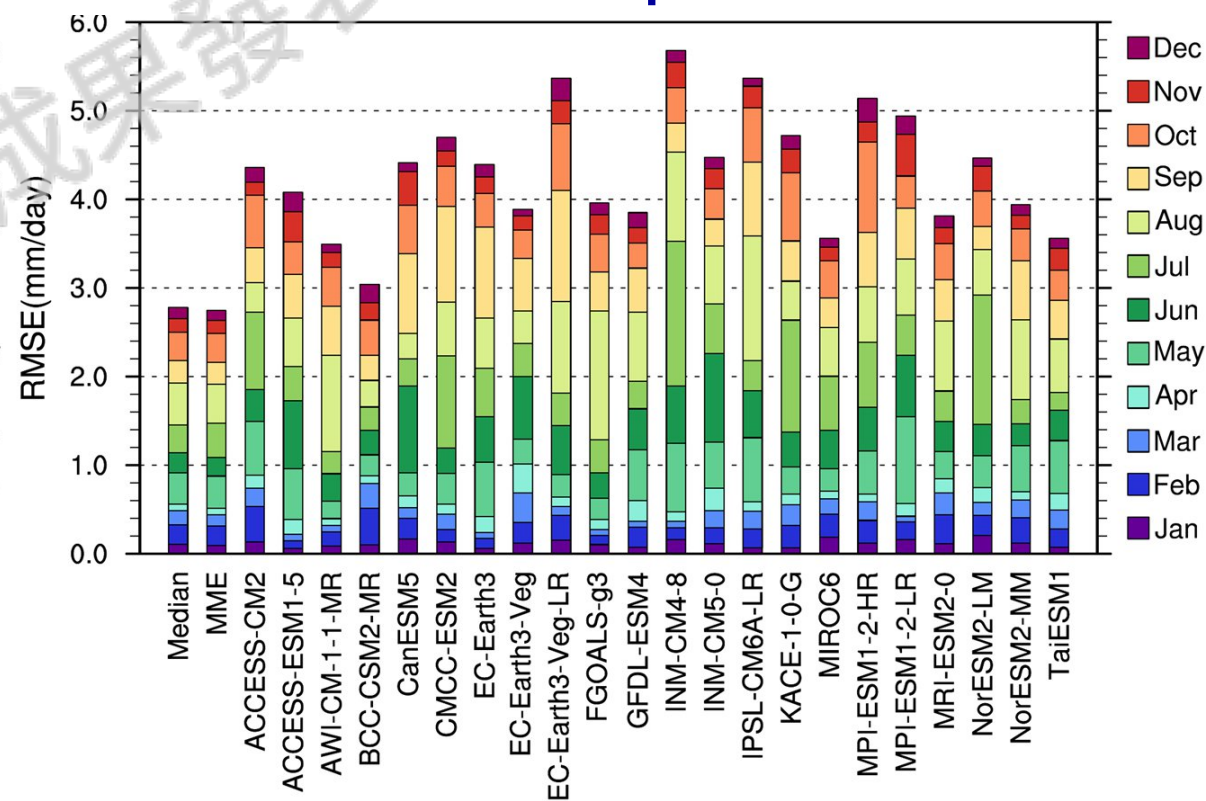
以歷史資料驗證統計降尺度結果

- The bias of monthly temperature is uniform.
- The large bias of Precipitation is in rainy seasons (May-Sep) and MME present the best result.

Temperature



Precipitation



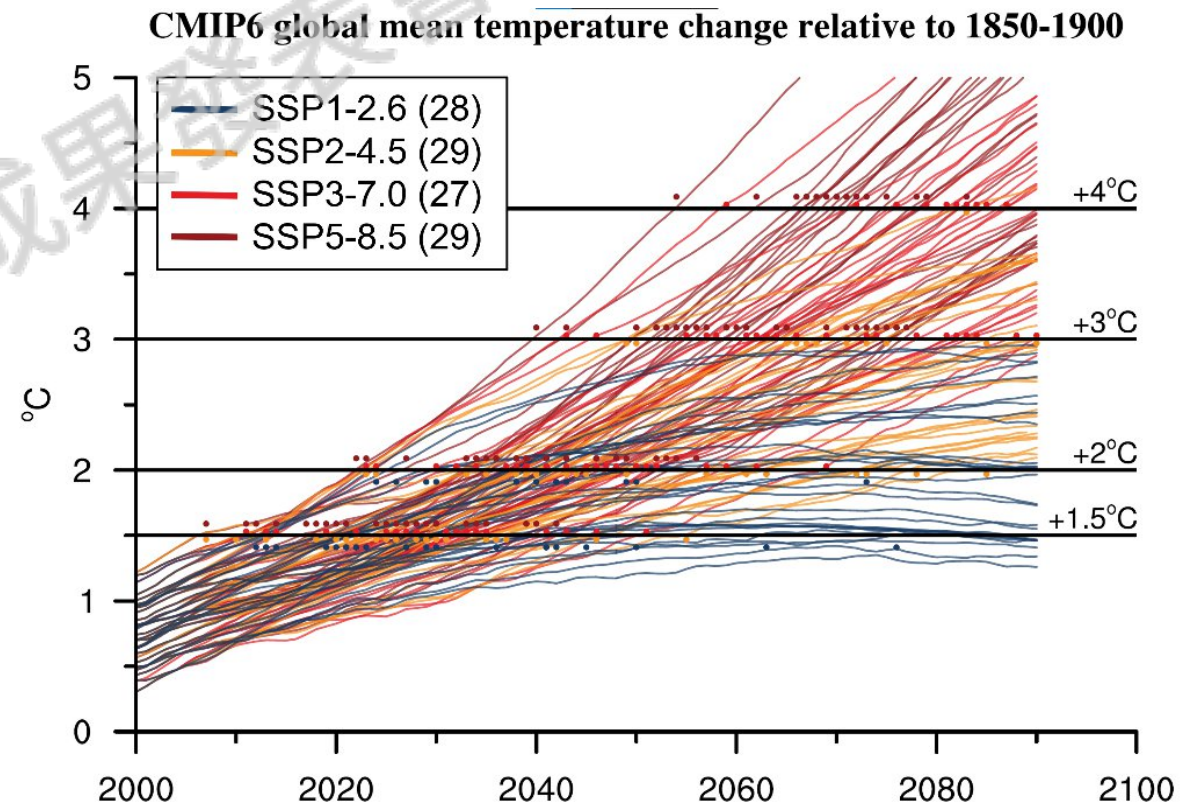
*The histograms with color bars reveal the monthly climatology in the period of 1960-2014

以全球暖化程度（GWL）降低不同未來氣候情境的不定性

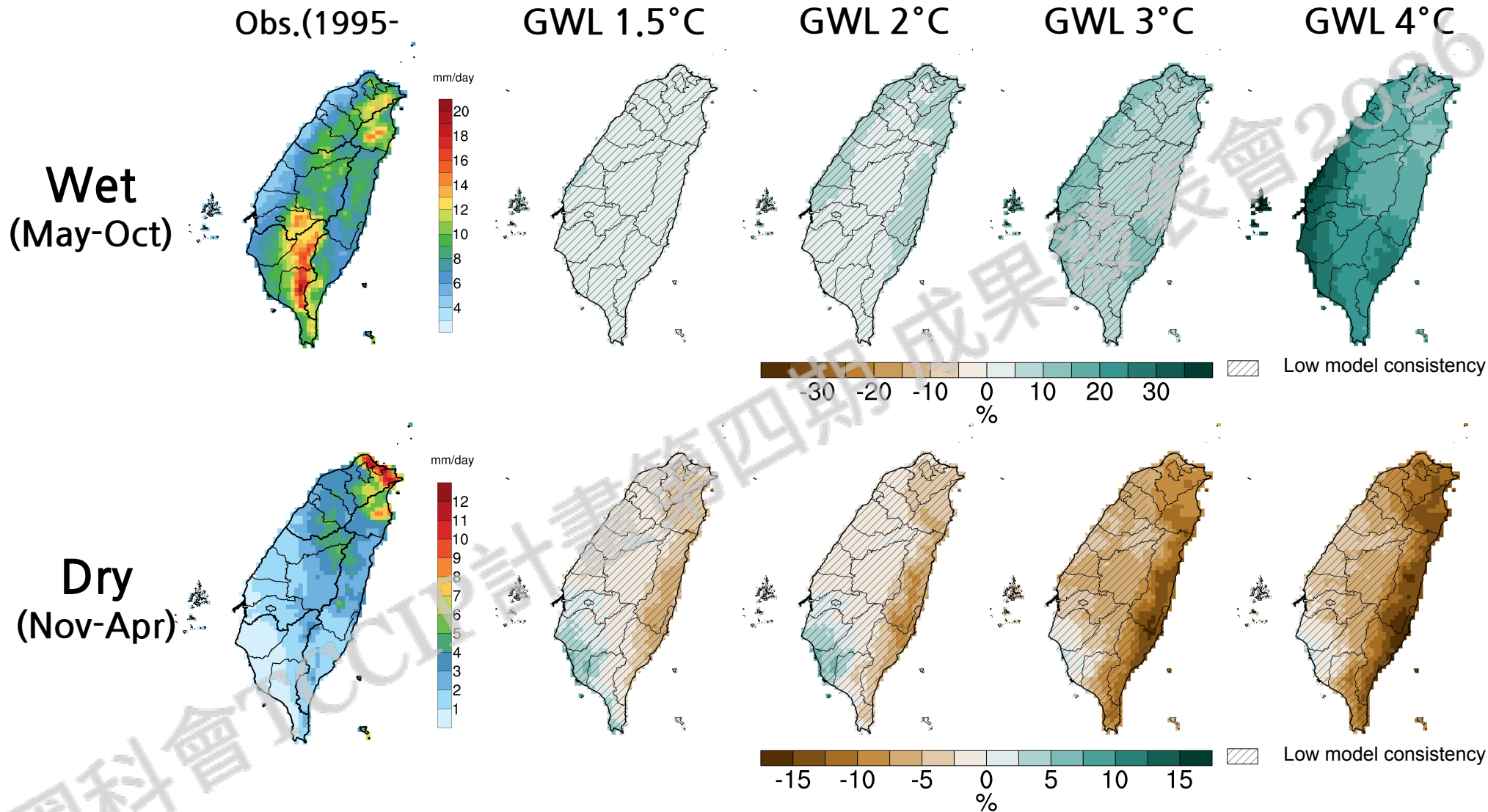
- **GWL (1.5°C, 2°C, 3°C and 4°C)**
 - Simplify application scenario
 - Notice decision-making timing

Based on IPCC AR6		
Global mean surface air temperature	Arrived period (Medium)	Very Likely (5-95%)
1.5°C	2029	2011-2064
2°C	2043	2022-2085
3°C	2064	2040-2087
4°C	2073	2054-2085

- **Statistical downscaling provides complete datasets**



不同全球暖化程度下的季節降雨變化



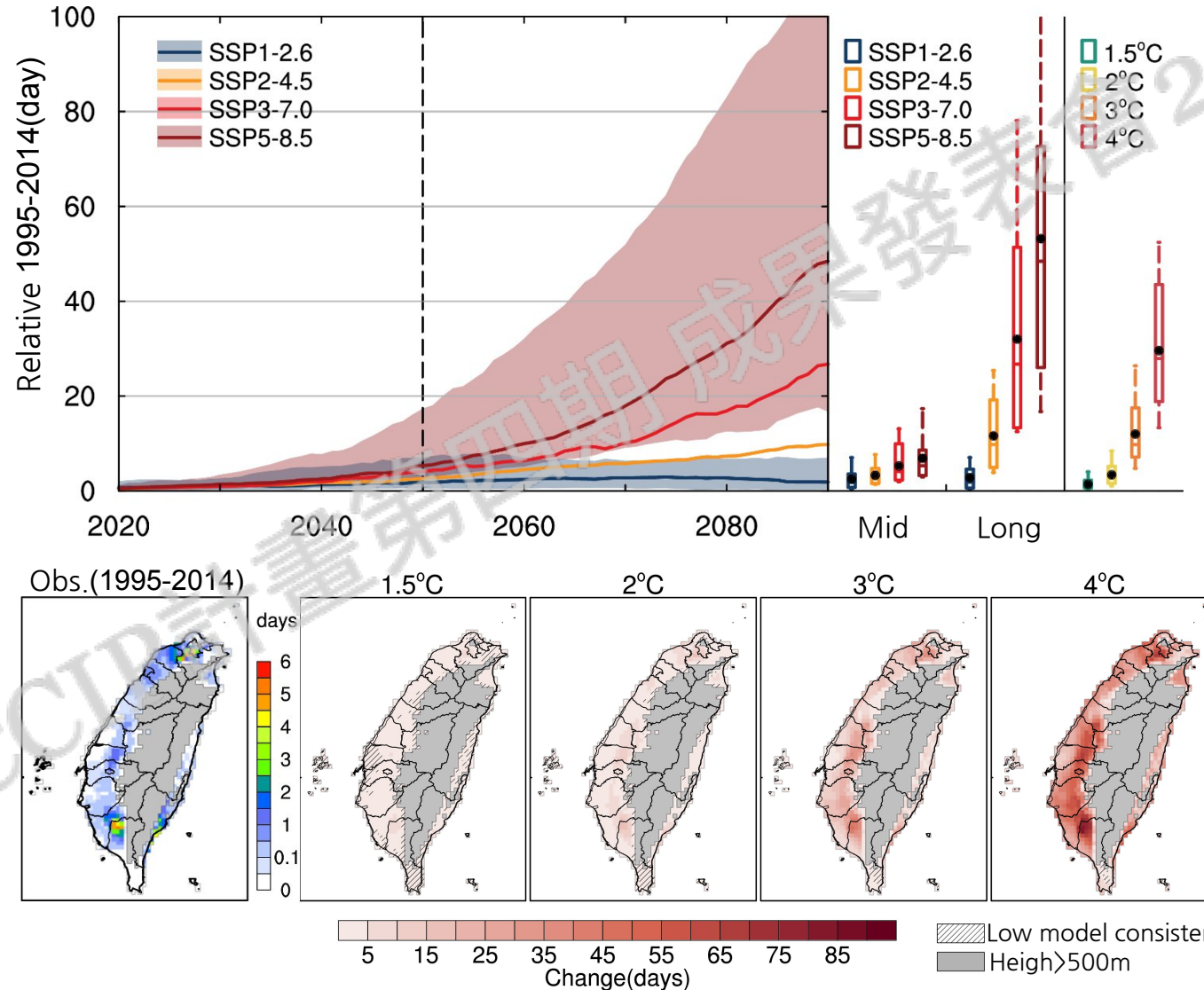
Climate Change in Taiwan:
National Scientific Report
2024



➤ Wet become wetter, and dry become drier

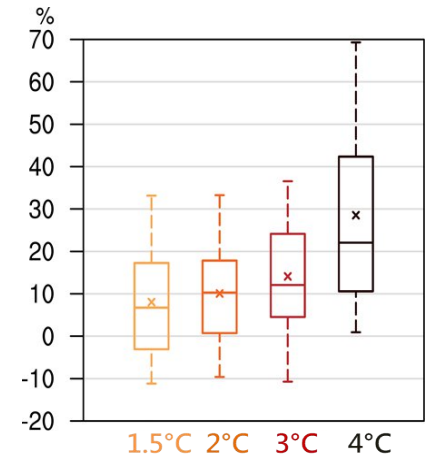
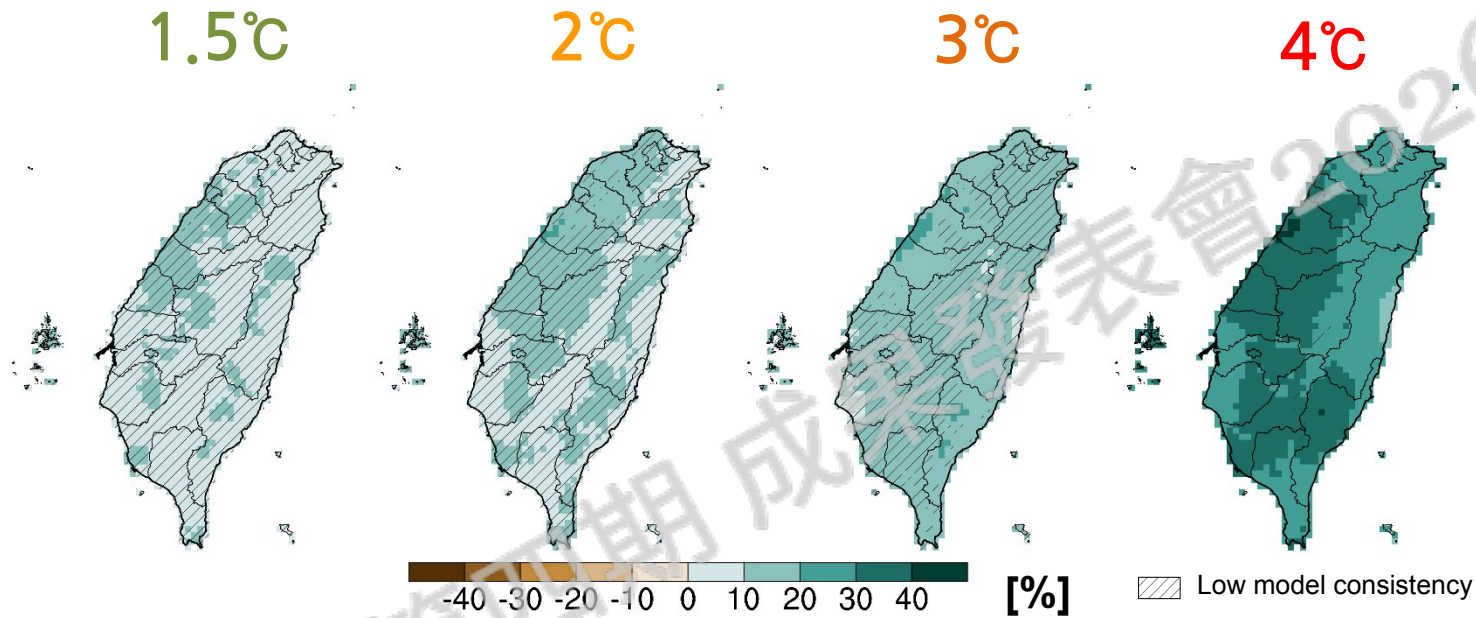
不同全球暖化程度對極端高溫發生頻率的影響

The number of days with daily max. temperature above 36°C

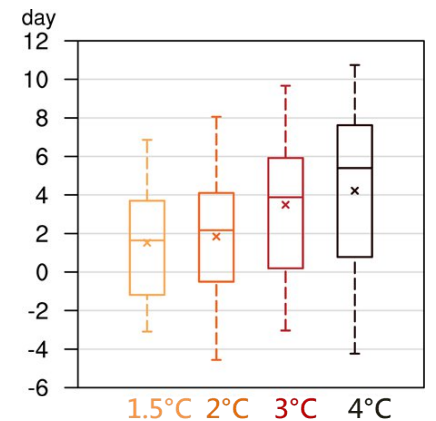
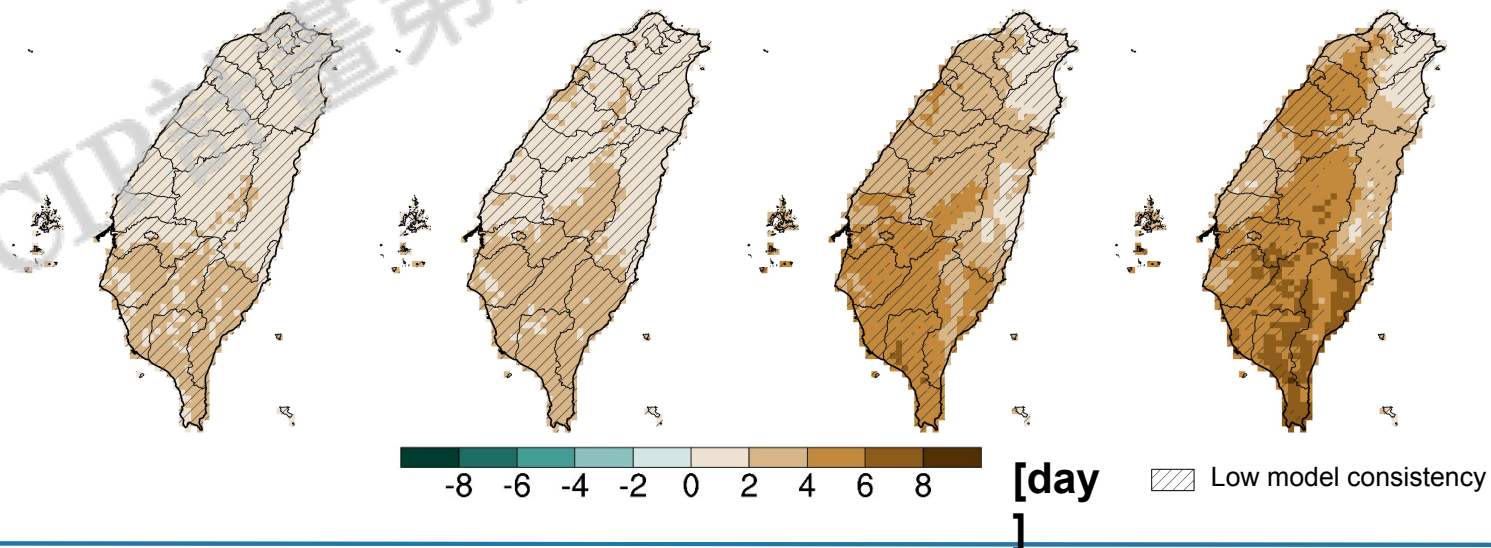


不同全球暖化程度對極端降雨與乾旱發生頻率的影響

Rx1day
(Annual Maximum 1-day
precipitation)

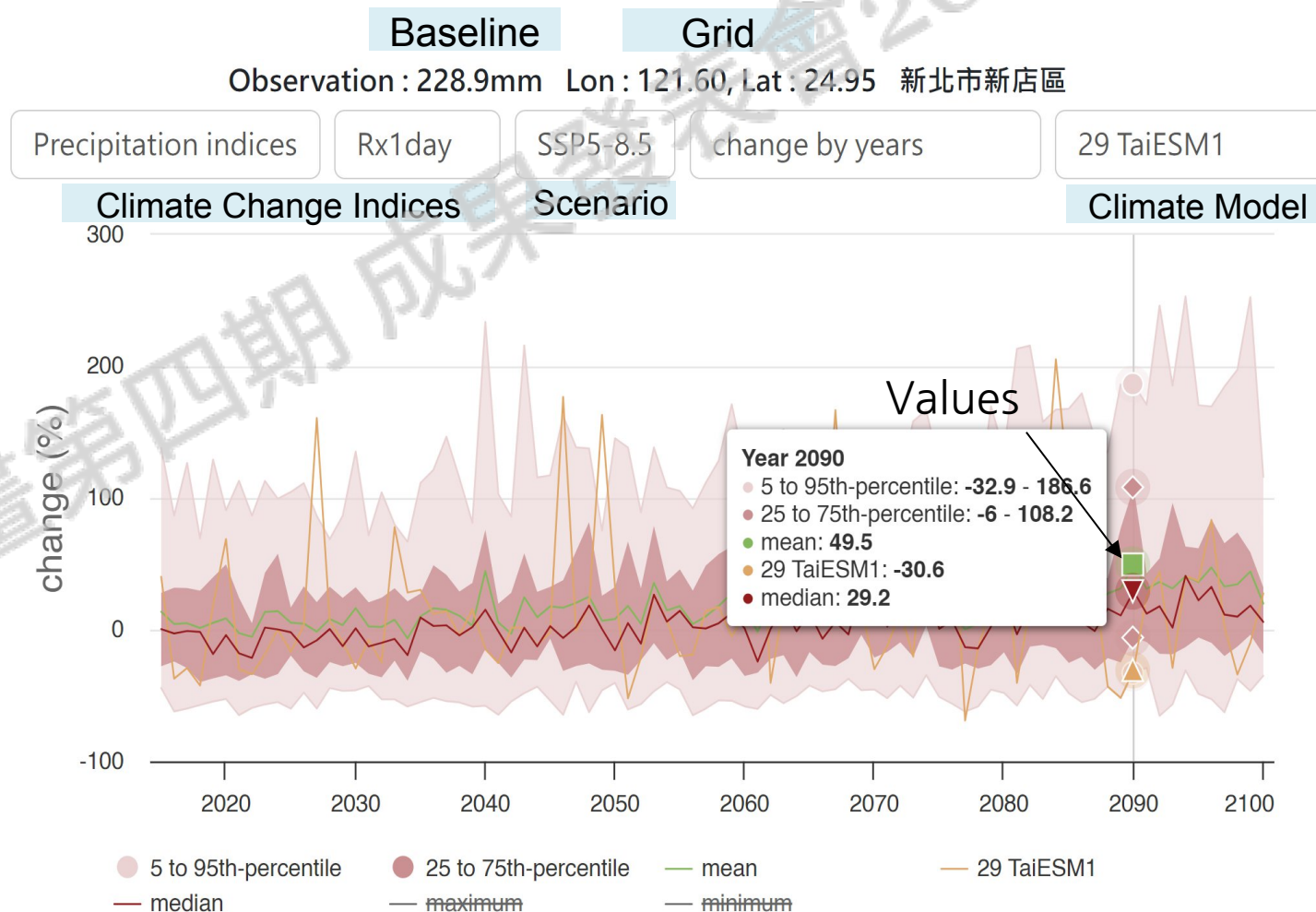
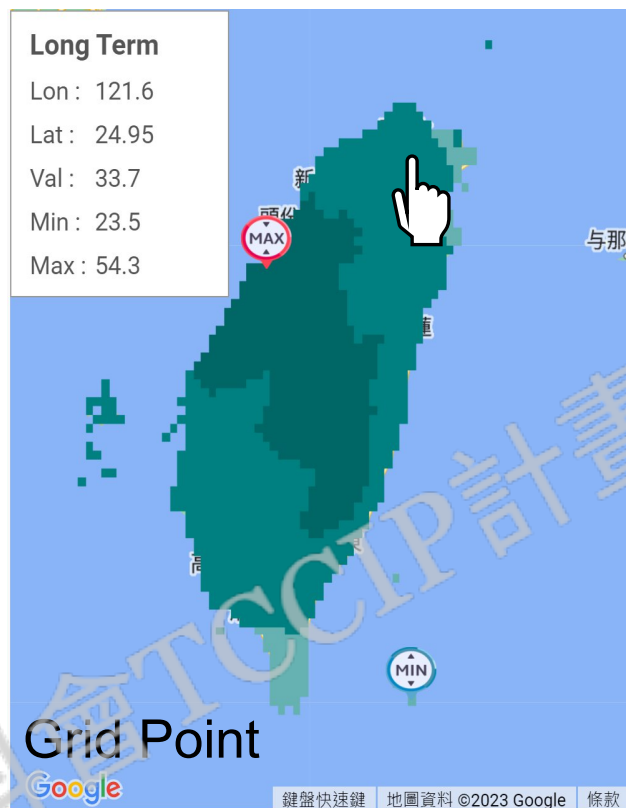


Drought
(Consecutive dry days)

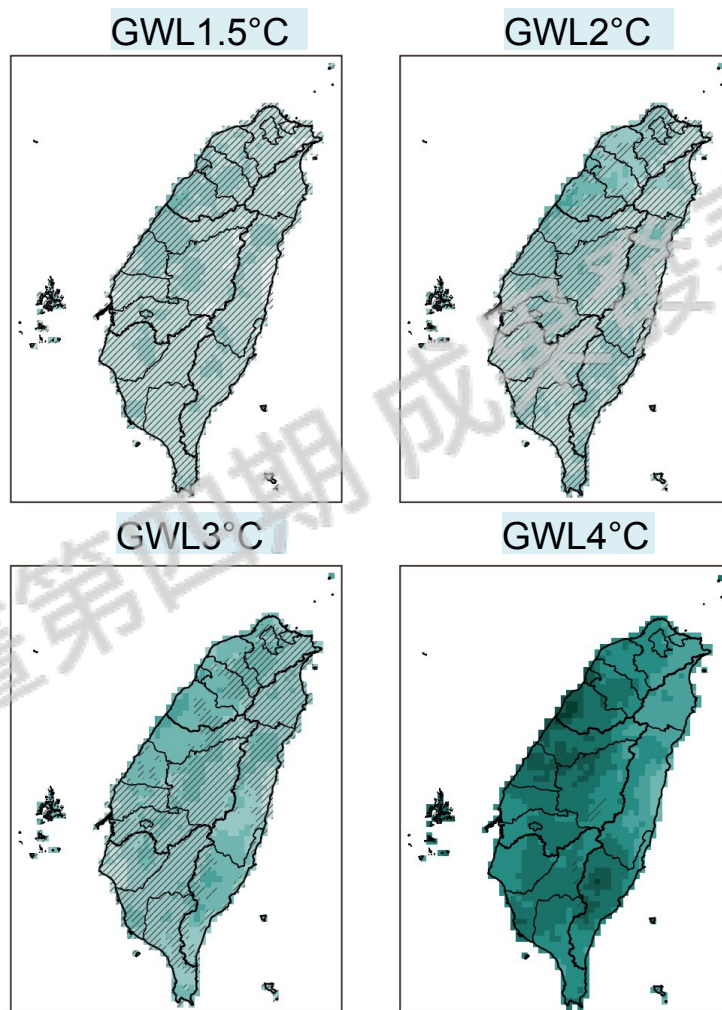


台灣氣候變遷關鍵指標的互動式地圖呈現

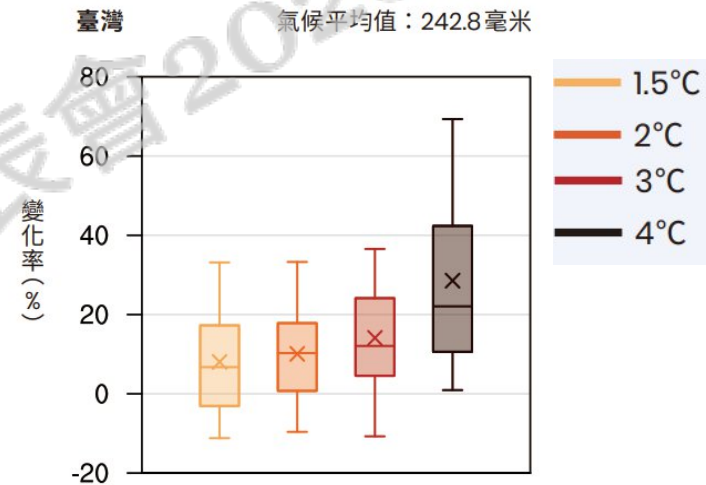
- 22 climate change indices (temperature and precipitation)
- 31 climate models, 4 SSP scenarios
- uncertainty range (likelihood range) of multi-model ensemble projections



台灣氣候變遷關鍵指標圖集



-40 -30 -20 -10 0 10 20 30 40 變化率(%)



臺灣 年最大一日降雨量 變化率(%)					
全球暖化	1.5°C	2°C	3°C	4°C	
系集平均	8	10.1	14.1	28.5	
百分位數	5	-11.2	-9.6	-10.7	0.9
	25	-3.1	0.7	4.5	10.6
	50	6.7	10.3	12.1	22.1
	75	17.3	17.8	24.1	42.4
	95	33.1	33.3	36.5	69.3

謝謝聆聽 敬請指教

Chen, C.-T., Y.-S. Tung, C.-Y. Wang, and S.-L. Lin, 2026: Assessing Taiwan's Future Climate: High Resolution Projections and Regional Impacts From Statistical Downscaling of CMIP6 Data, International Journal of Climatology, e70431

<https://doi.org/10.1002/joc.70431>



<https://tccip.ncdr.nat.gov.tw>

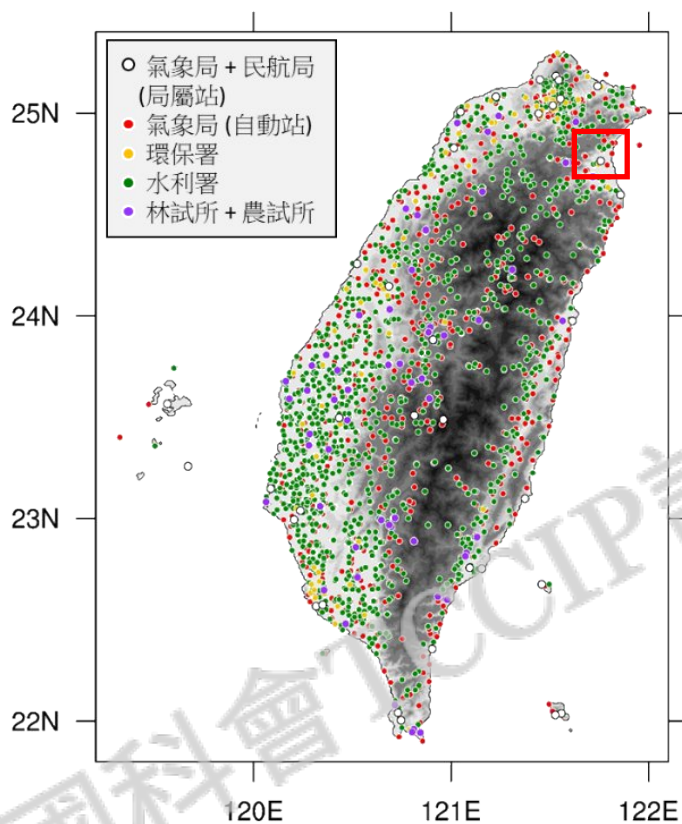


TCCIP FB

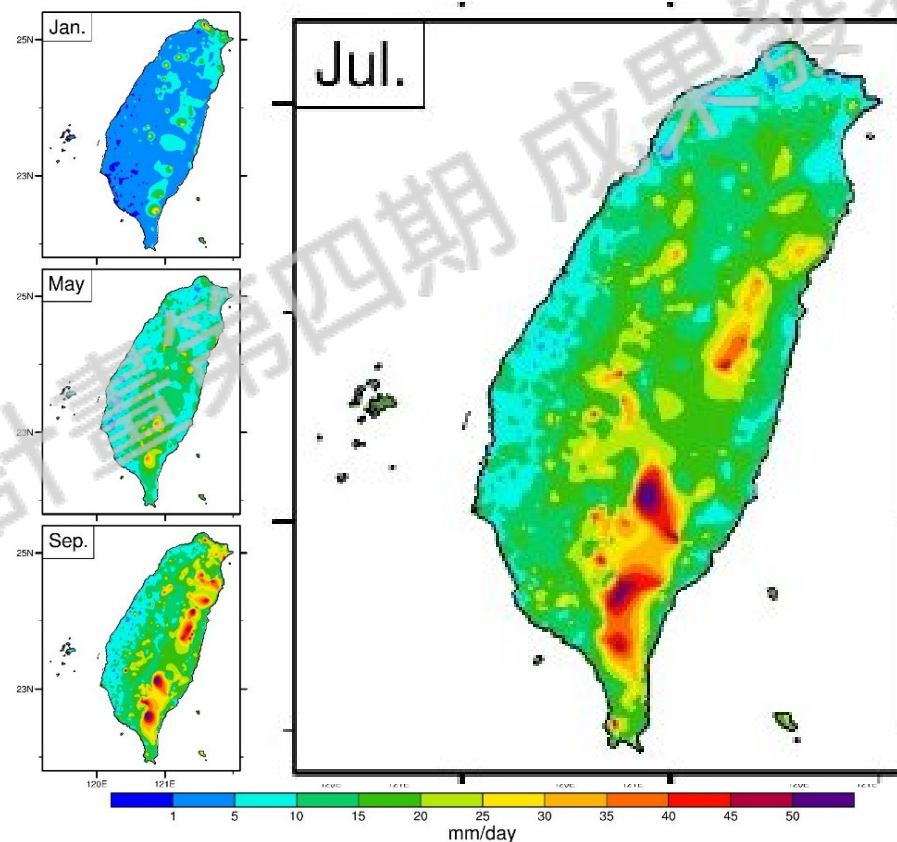
網格化觀測資料的不確定性

- **網格化不確定性**：山區測站密度低，加上溫度與雨量空間變異大，資料不確定性較高
平地測站較密，資料不確定性較小
- **測站資料不確定性**：增撤站、儀器故障、維修、更新…造成資料長度與品質的不連續

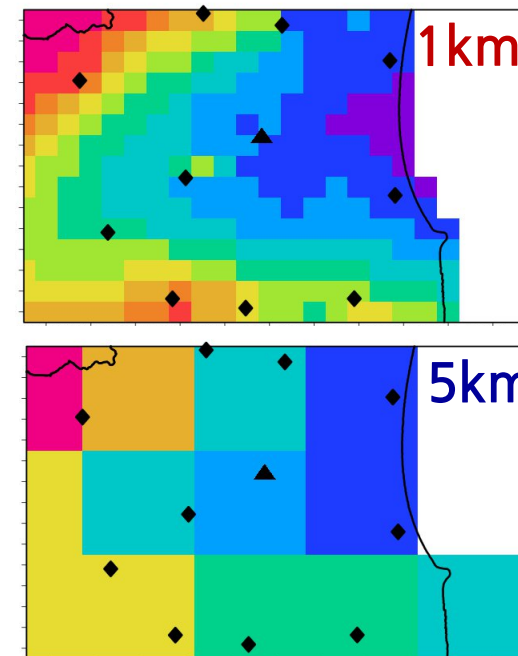
測站分布圖



網格化觀測降雨不確定性 (均方根誤差)



蘭陽平原



蘭陽平原測站密度接近
每5公里網格1個站