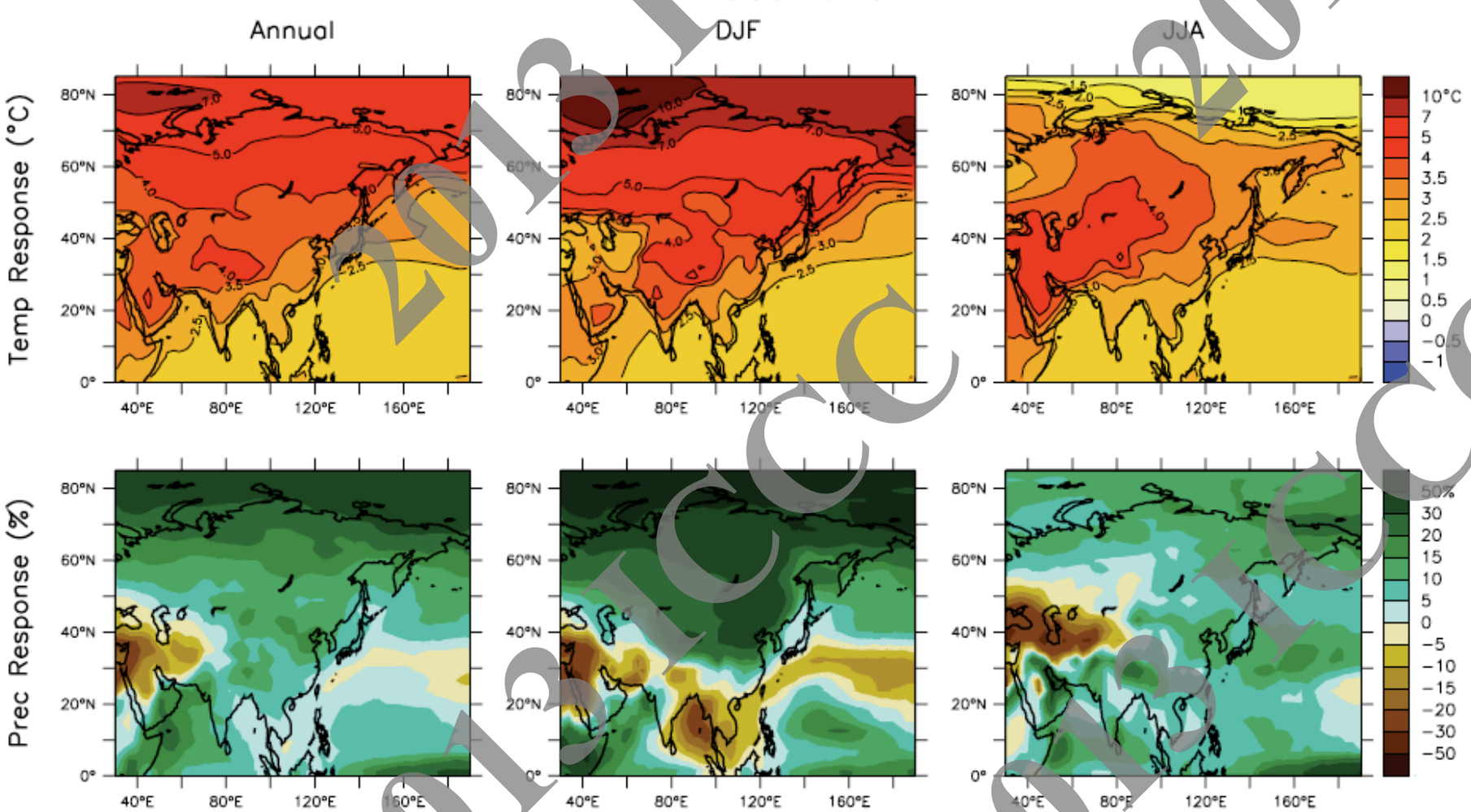
以統計方法提供台灣未來氣候變遷推估的區域細節與機率分佈：從平均氣候狀態到極端天氣與氣候指標

陳正達、林修立、駱世豪、童裕翔　台灣師範大學地球科學系暨海洋環境科技研究所
臺灣氣候變遷推估與資訊平台建置計畫　降尺度工作小組成員



- 為什麼需要降尺度？
- 如何推算區域細節？
- 如何處理氣候推估的不確定性？
- 主要的成果與必須注意的限制

為什麼需要降尺度？

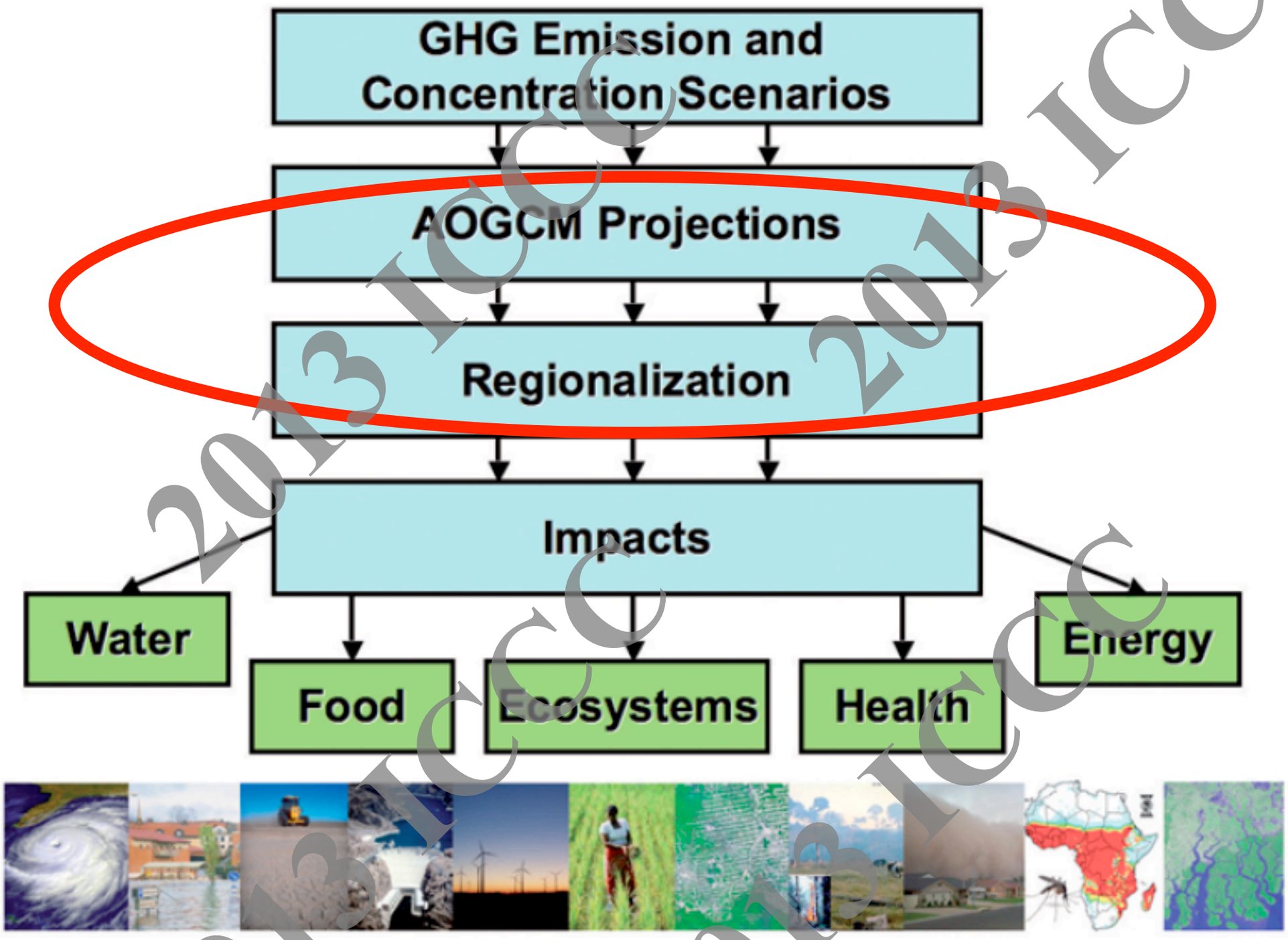
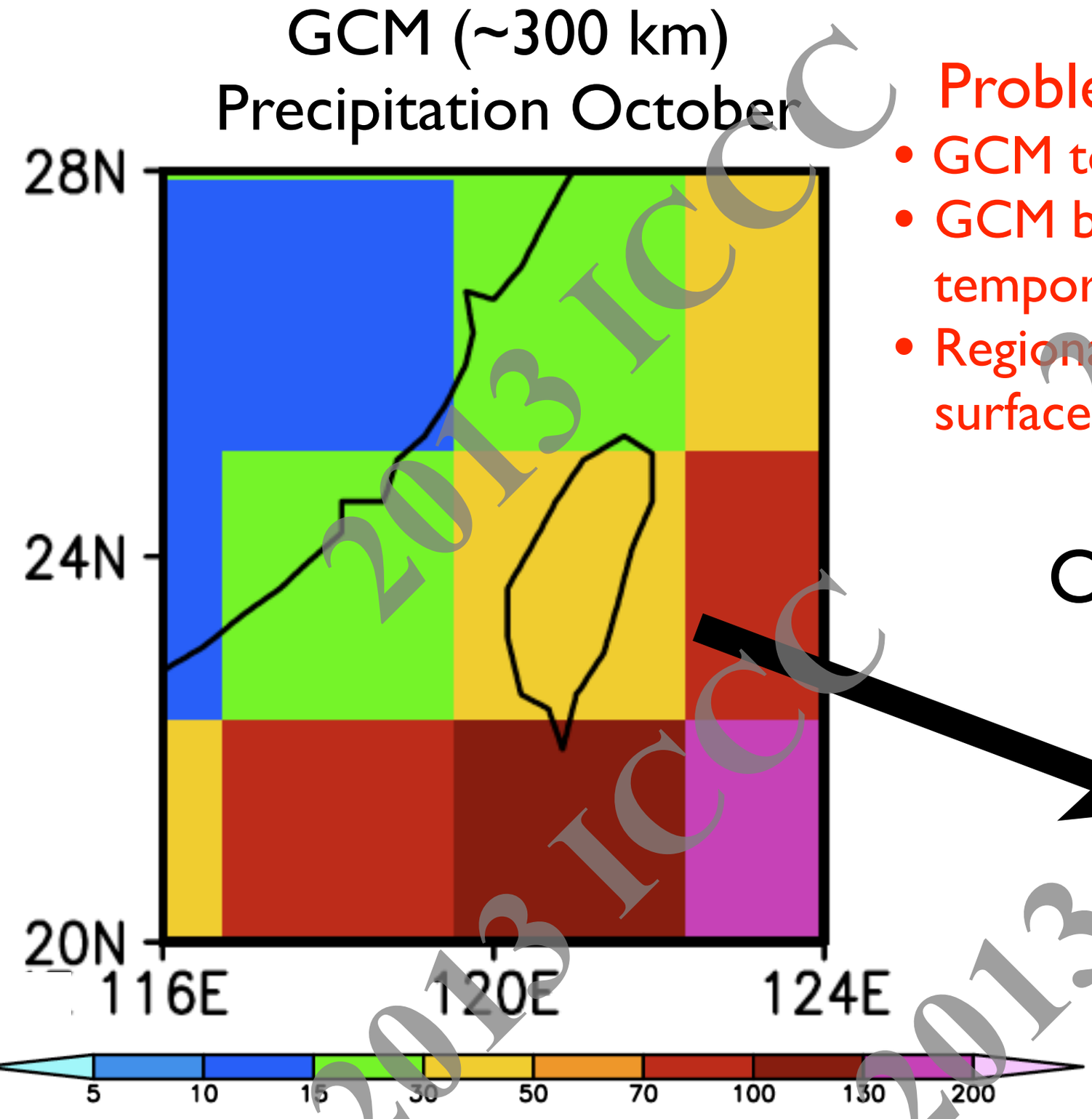


Figure 3 — Schematic depiction of the steps involved in the production of climate change information usable for impact assessment work via regionalization methods

Source: Giorgi (2008)

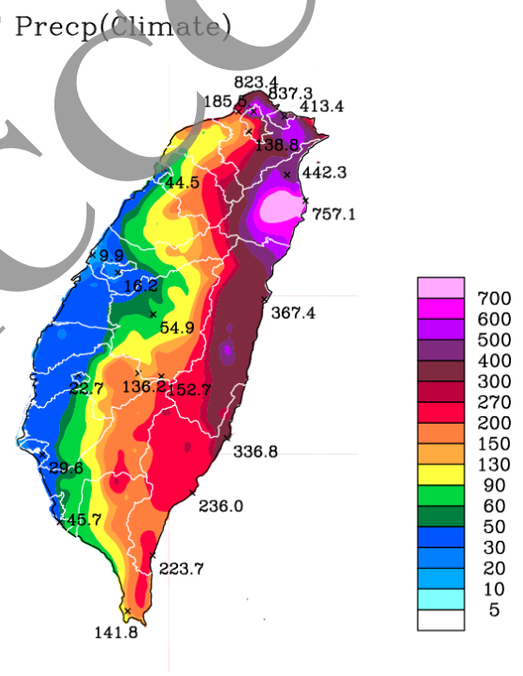
為什麼需要降尺度？



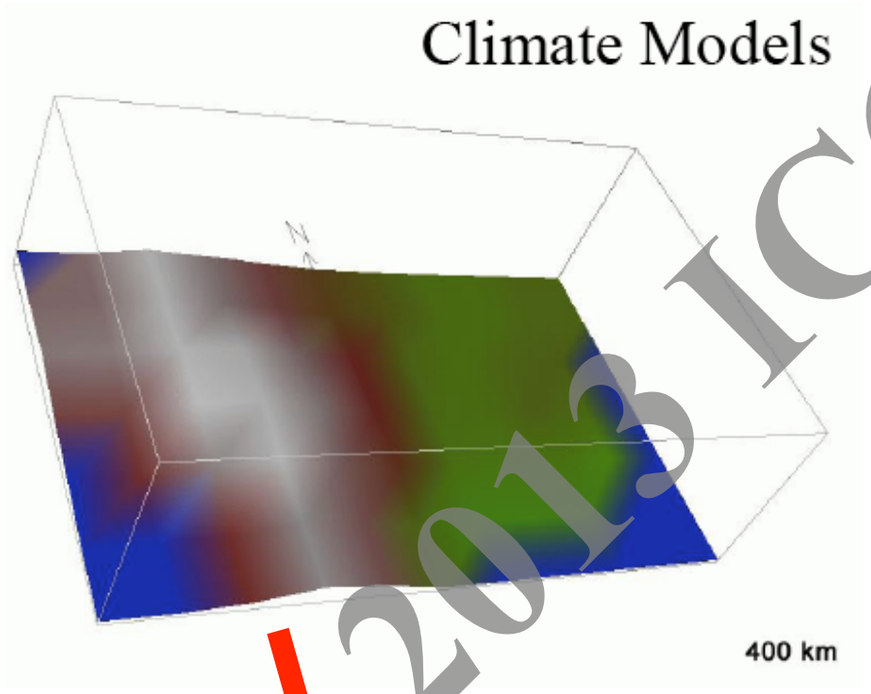
Problems:

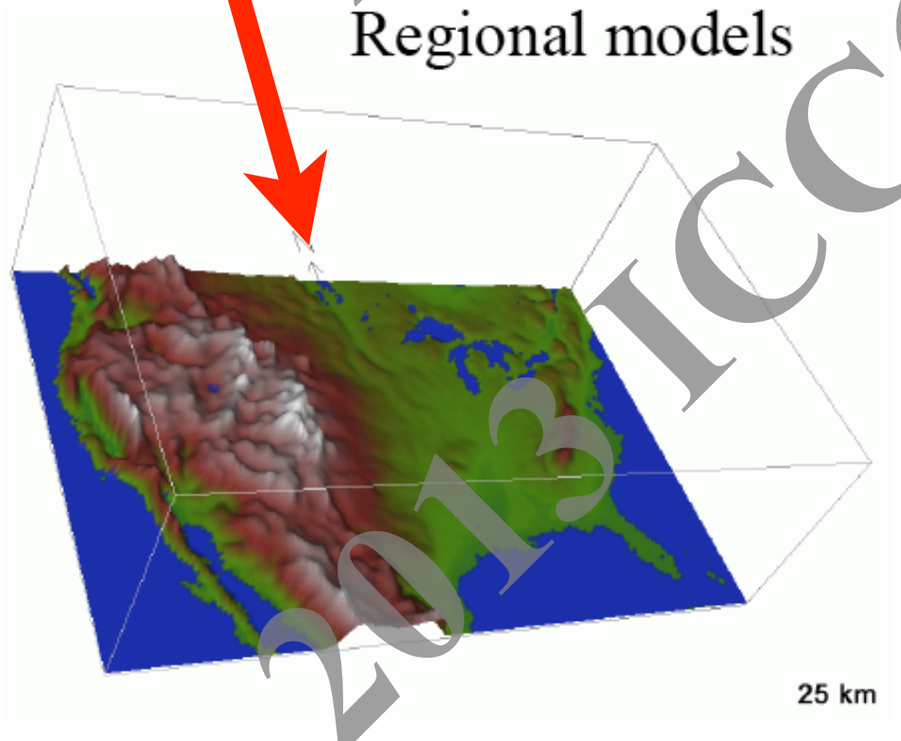
- GCM too coarse for local assessment
- GCM biases in climatology (spatially and temporally)
- Regional climate variability (topography, surface landscapes, coastlines)

Observation (~5km)



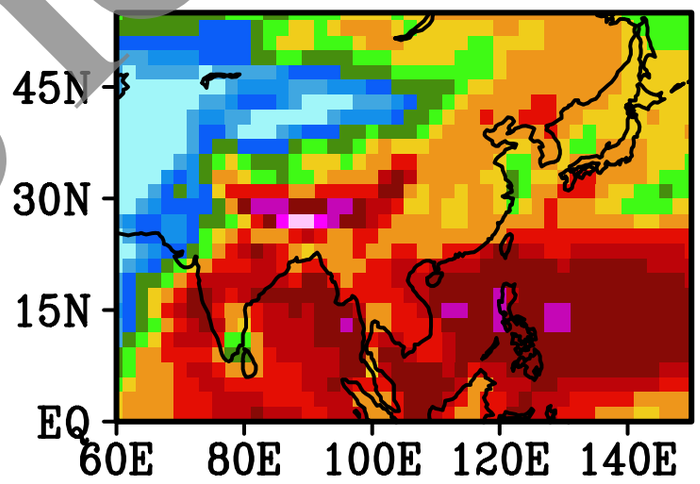
動力降尺度
Dynamical Downscaling



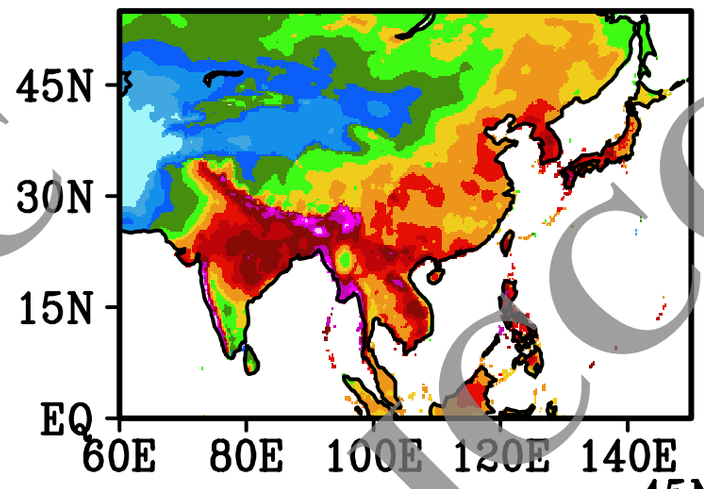


統計降尺度
Statistical Downscaling

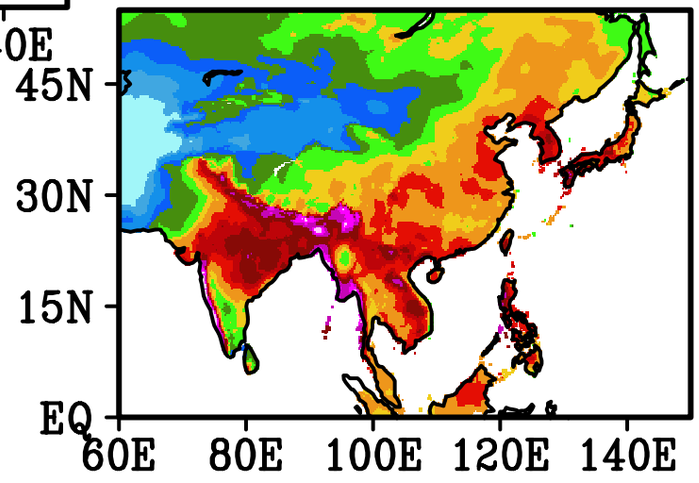
Climate Model



High Resolution Observation



Downscaled



為什麼選擇統計降尺度？

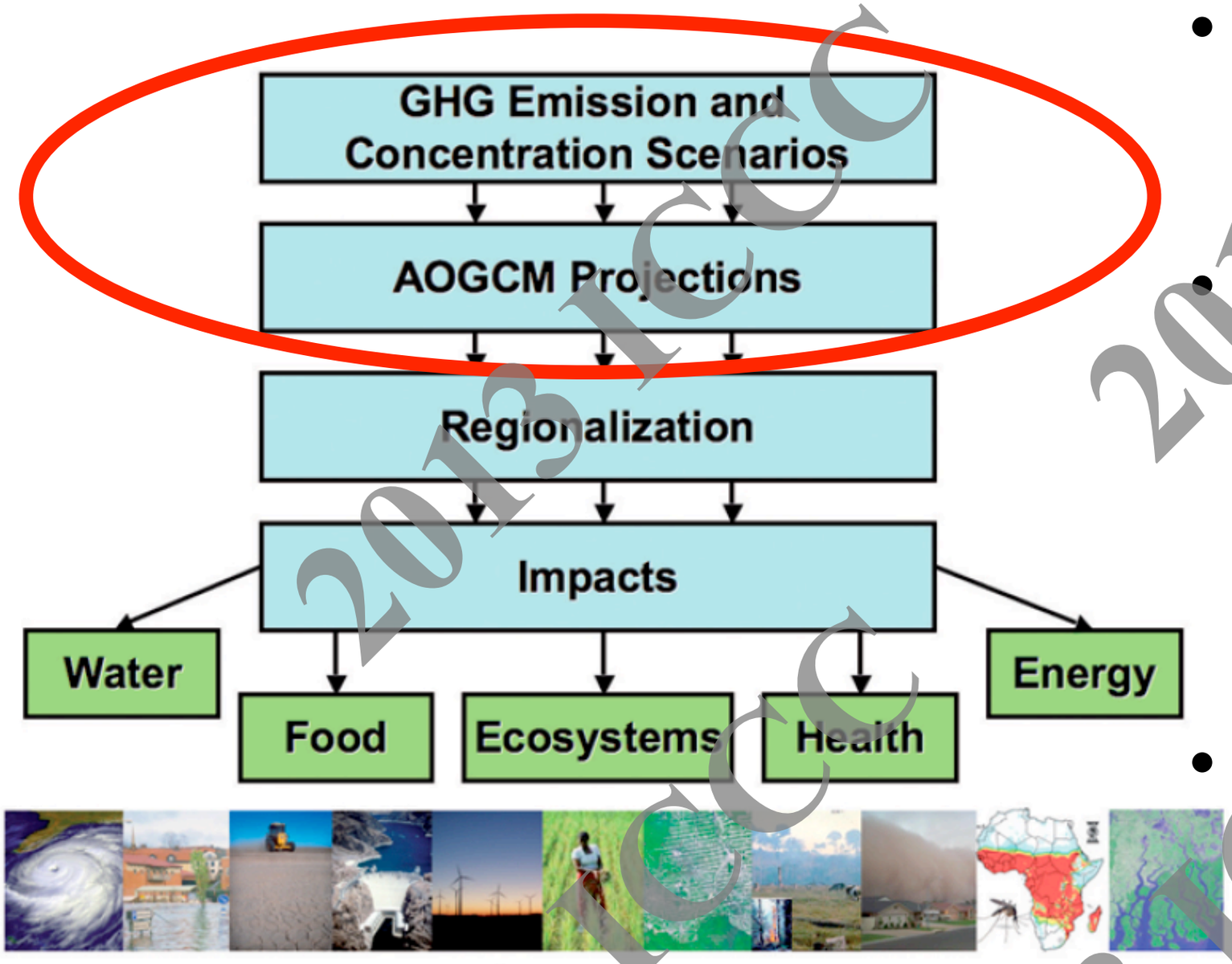


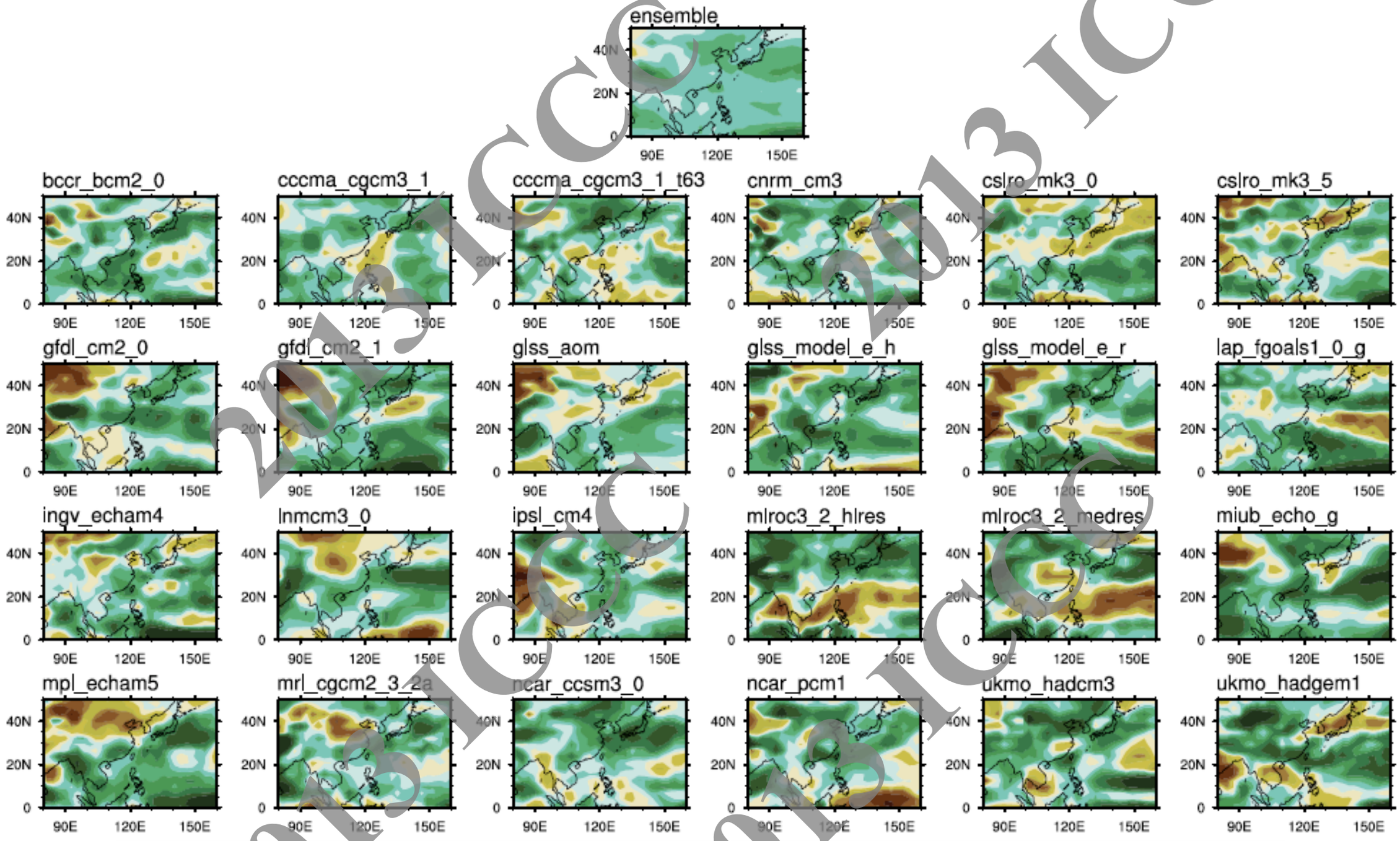
Figure 3 — Schematic depiction of the steps involved in the production of climate change information usable for impact assessment work via regionalization methods

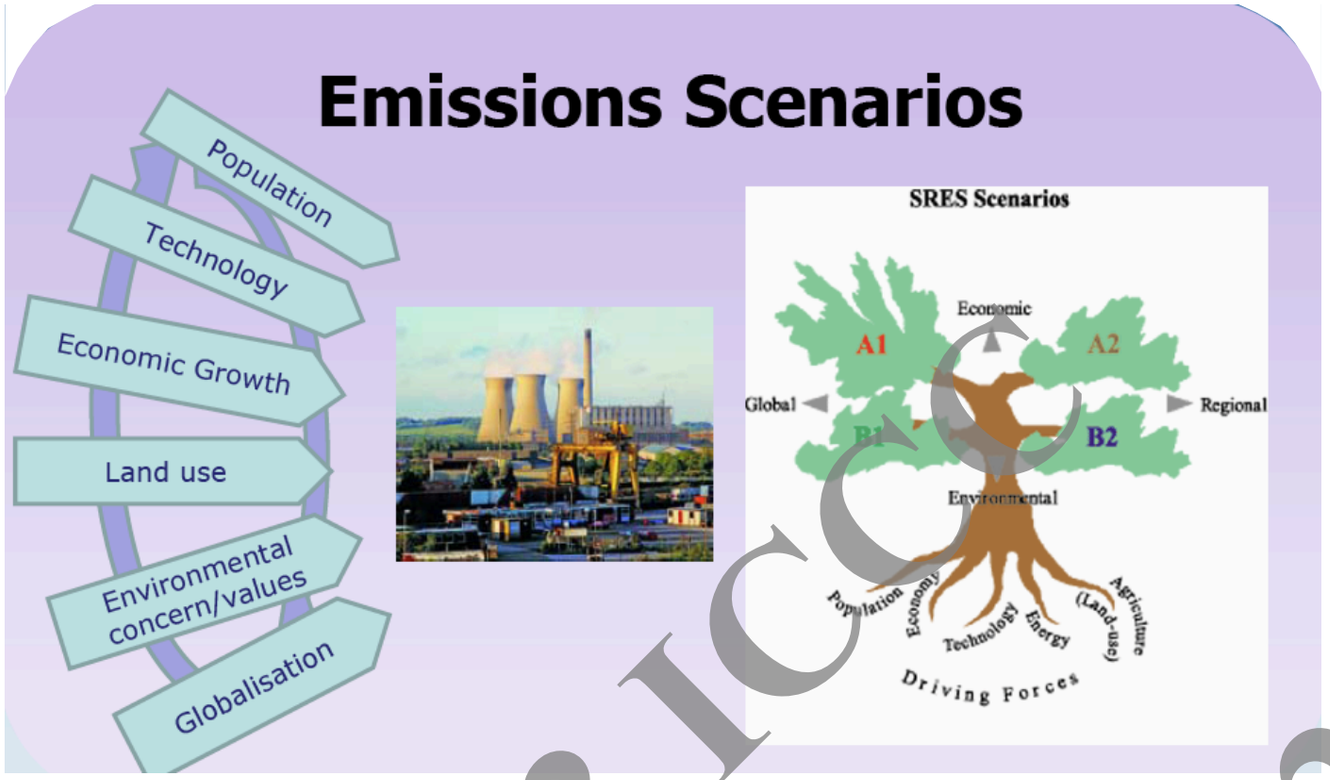
Source: Giorgi (2008)

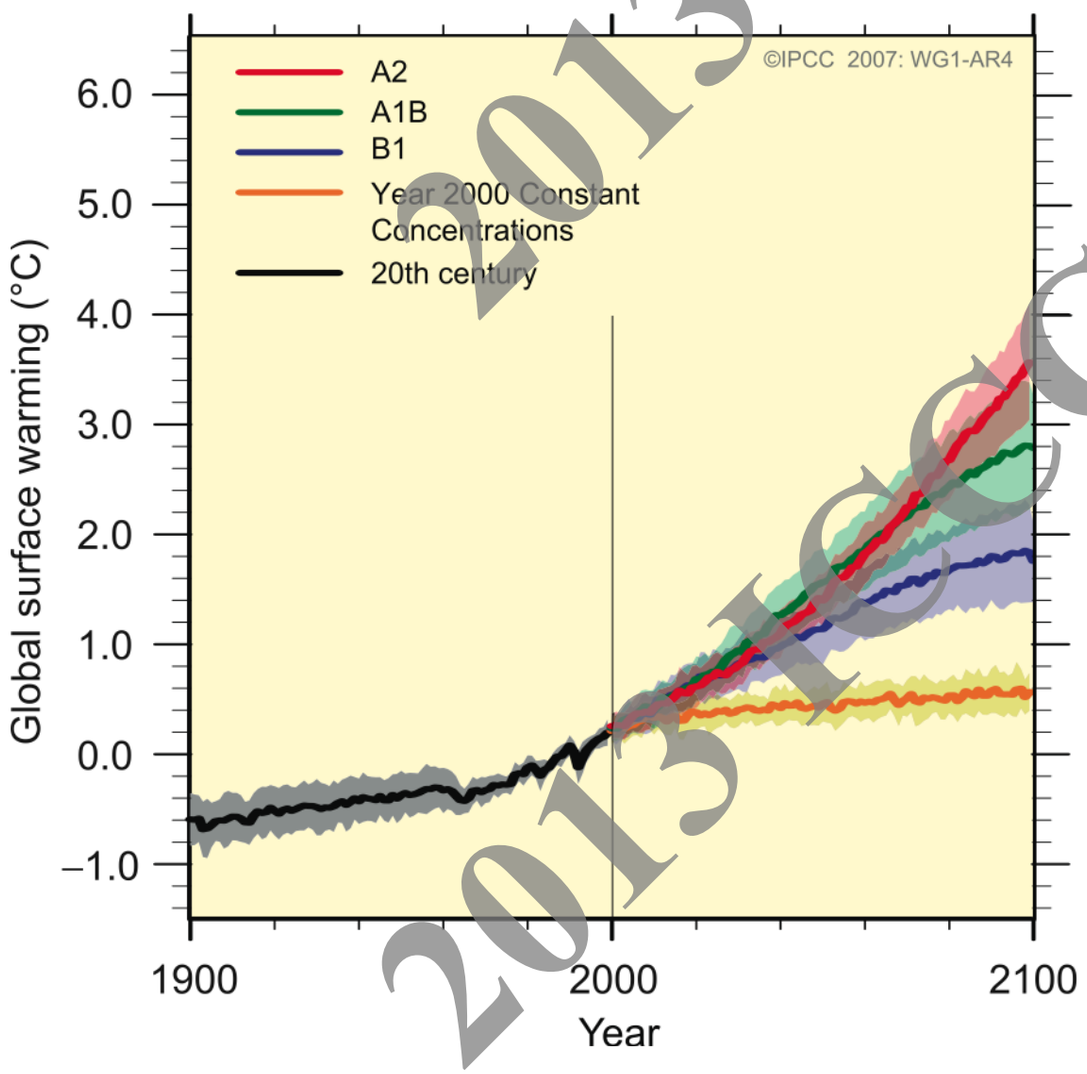
- Uncertainties in future greenhouse gas and aerosol emissions
- Uncertainties in global and regional climate sensitivity, due to differences in the way physical processes and feedbacks are simulated in different models
- It is much more resources demanding to cover all the above uncertainty sources with dynamical downscaling

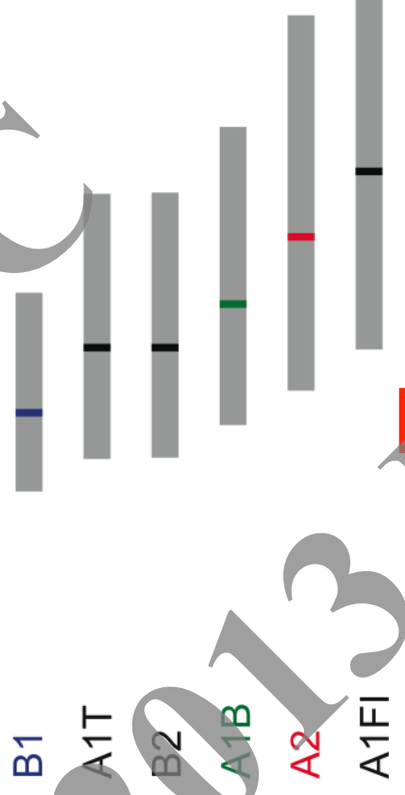
Uncertainty from Global Climate Models

Summer precipitation change(%) with all IPCC AR4 models under A1B scenario









Keep the uncertainty

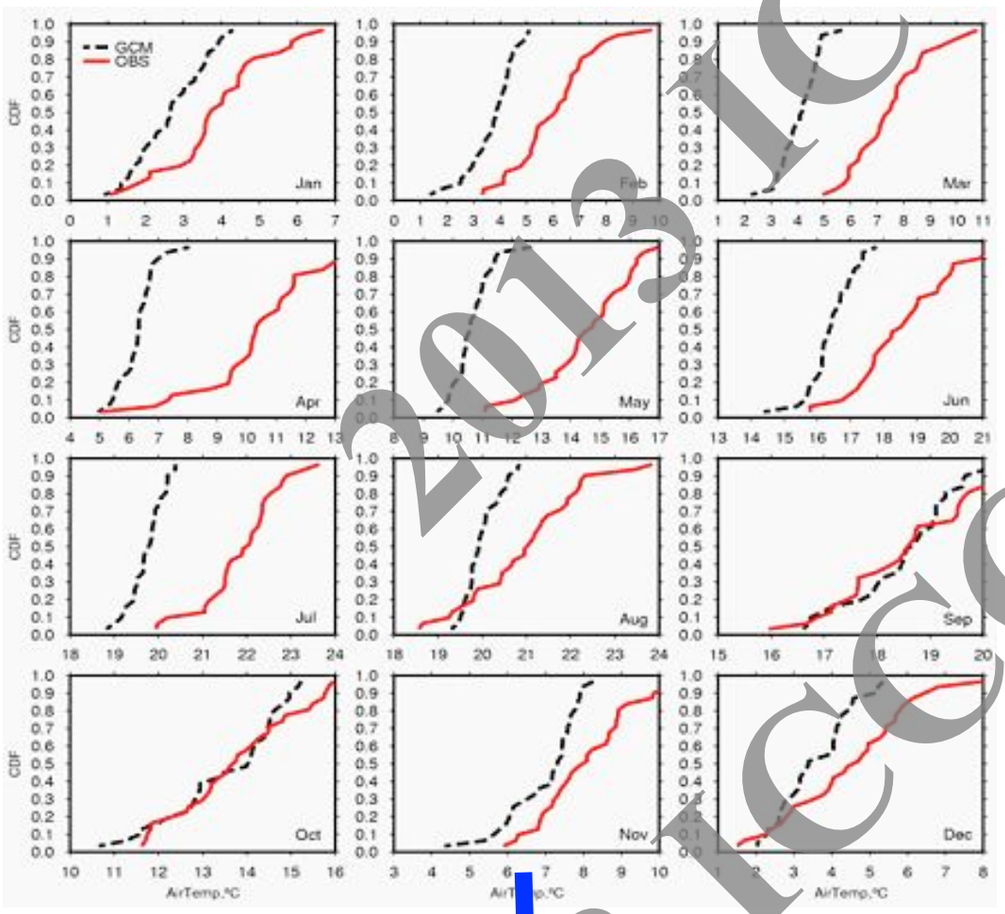
- Uncertainties in future greenhouse gas and aerosol emissions
- Uncertainties in global and regional climate sensitivity, due to differences in the way physical processes and feedbacks are simulated in different models

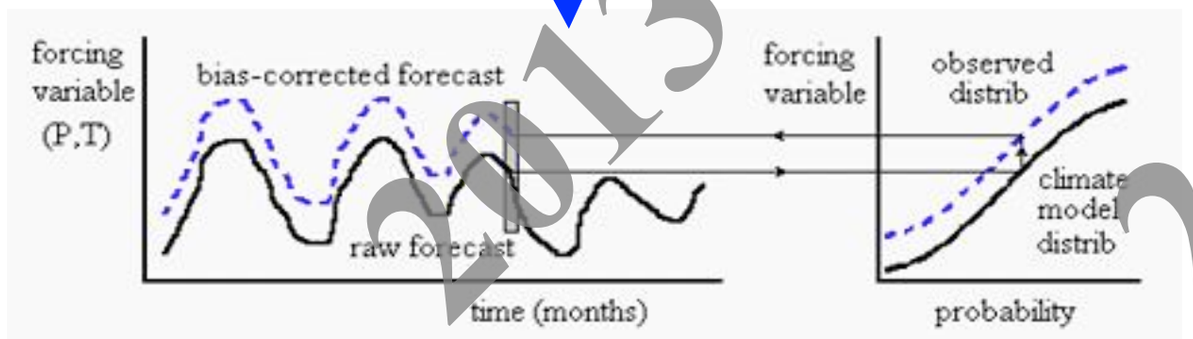
Probabilistic model future climate projection for individual scenarios

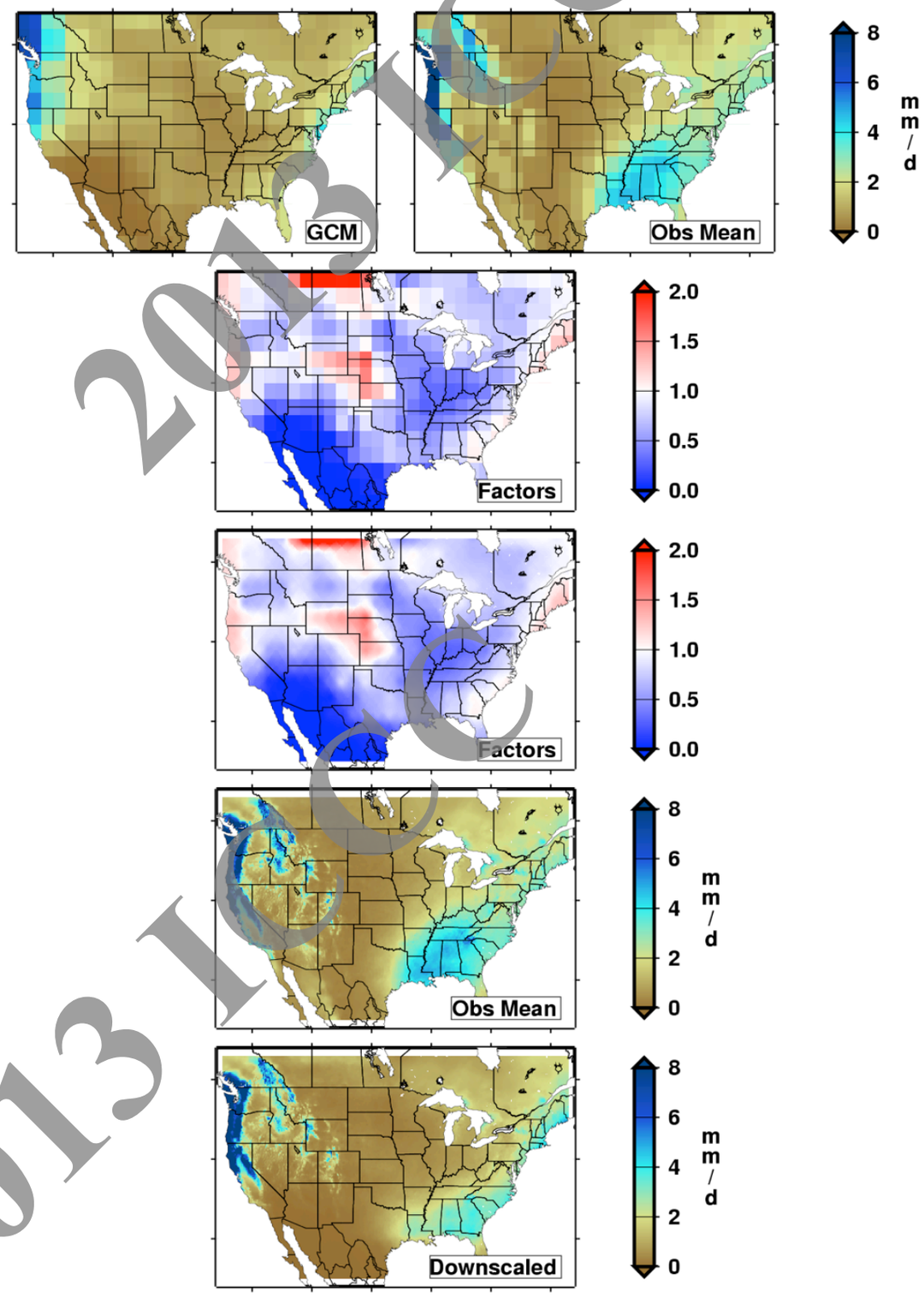
Statistical Downscaling

Wood et al. 2004, and Maurer 2007

Statistical downscaling and bias correction by cumulative distribution function and interpolation

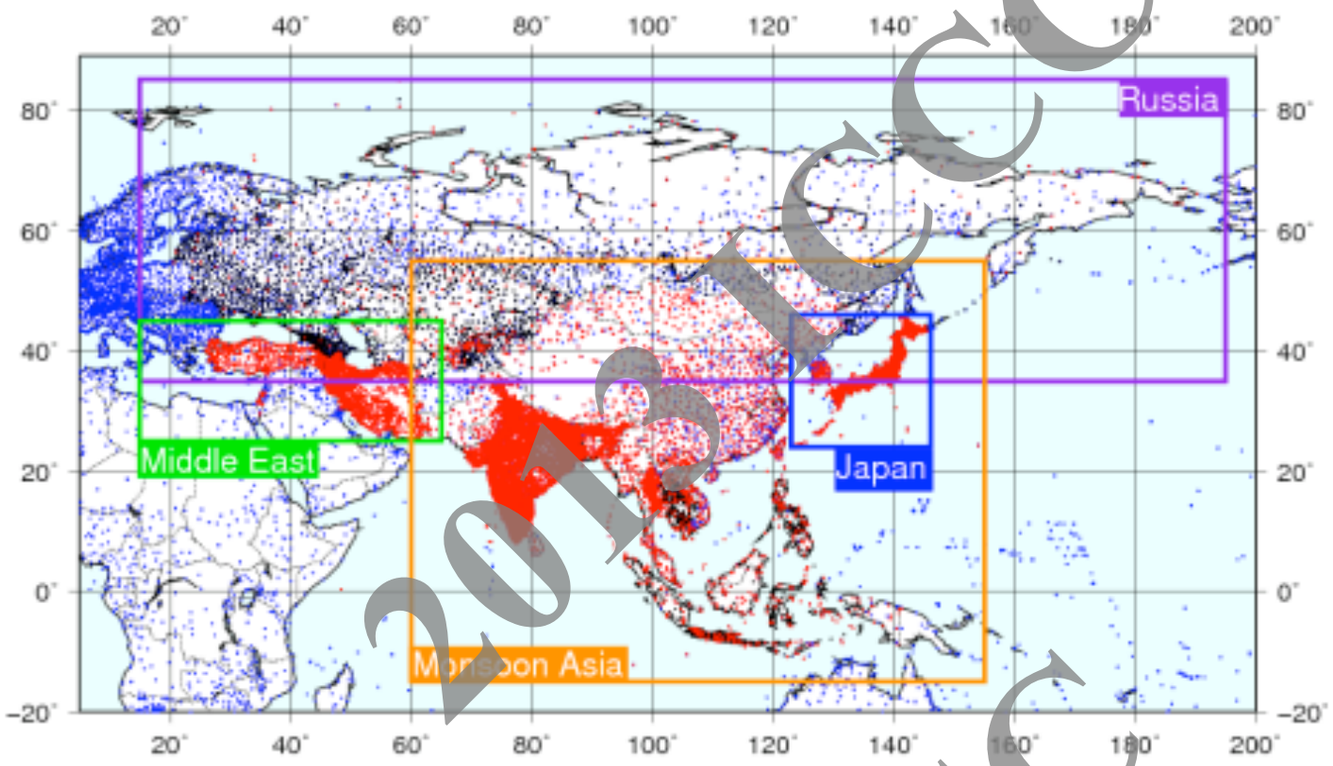




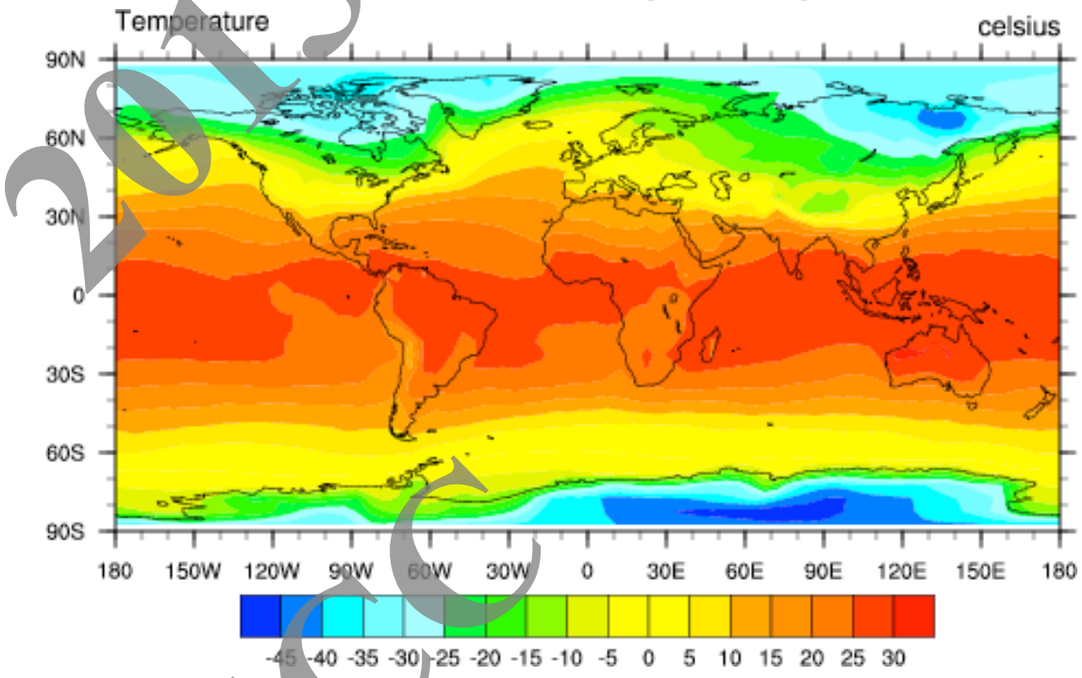


Require long-term high-resolution observations

APHRODITE (0.25°)



CRU (0.5°)

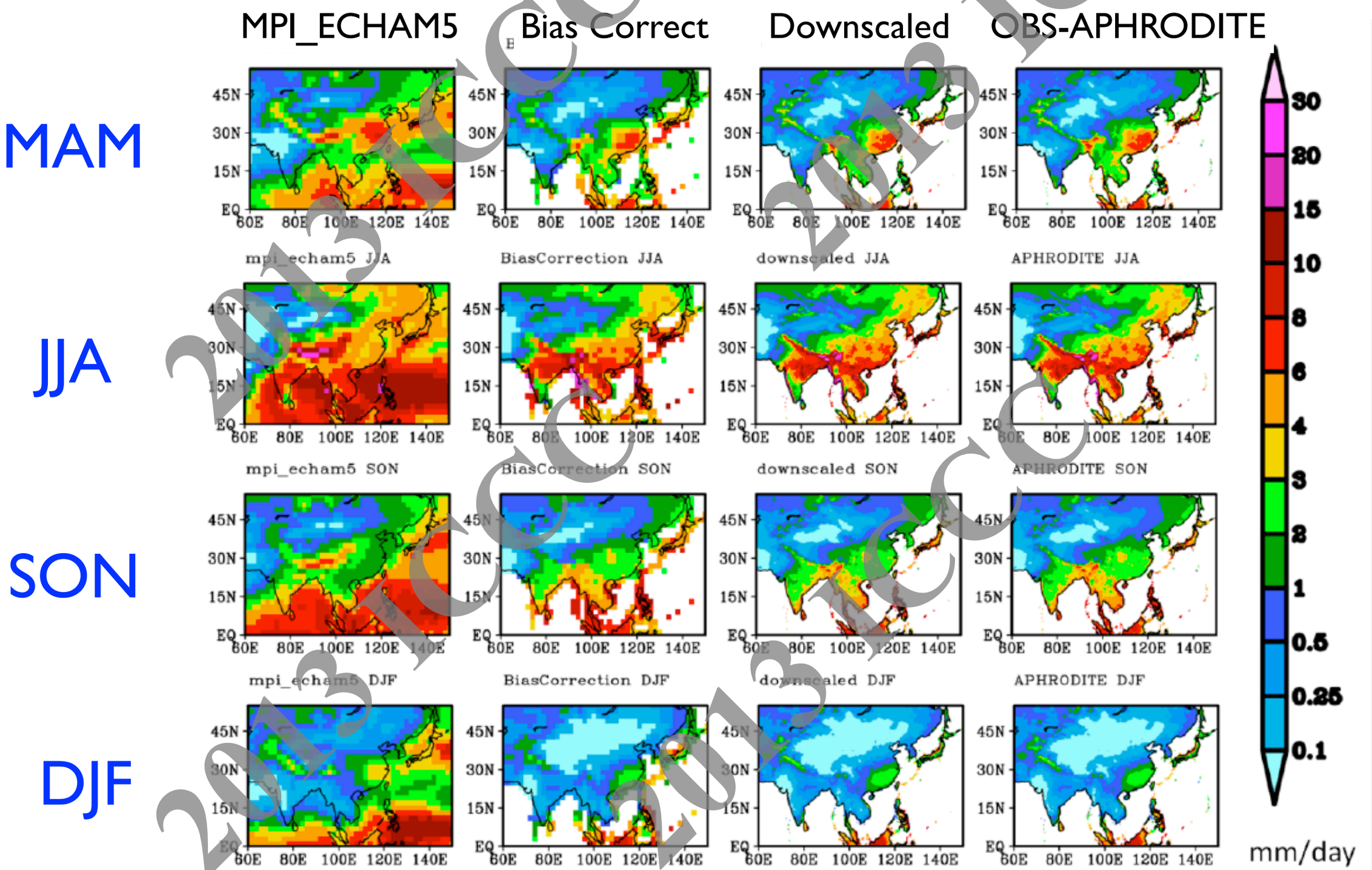


Current version: V1003R1 Download »Readme »Errata

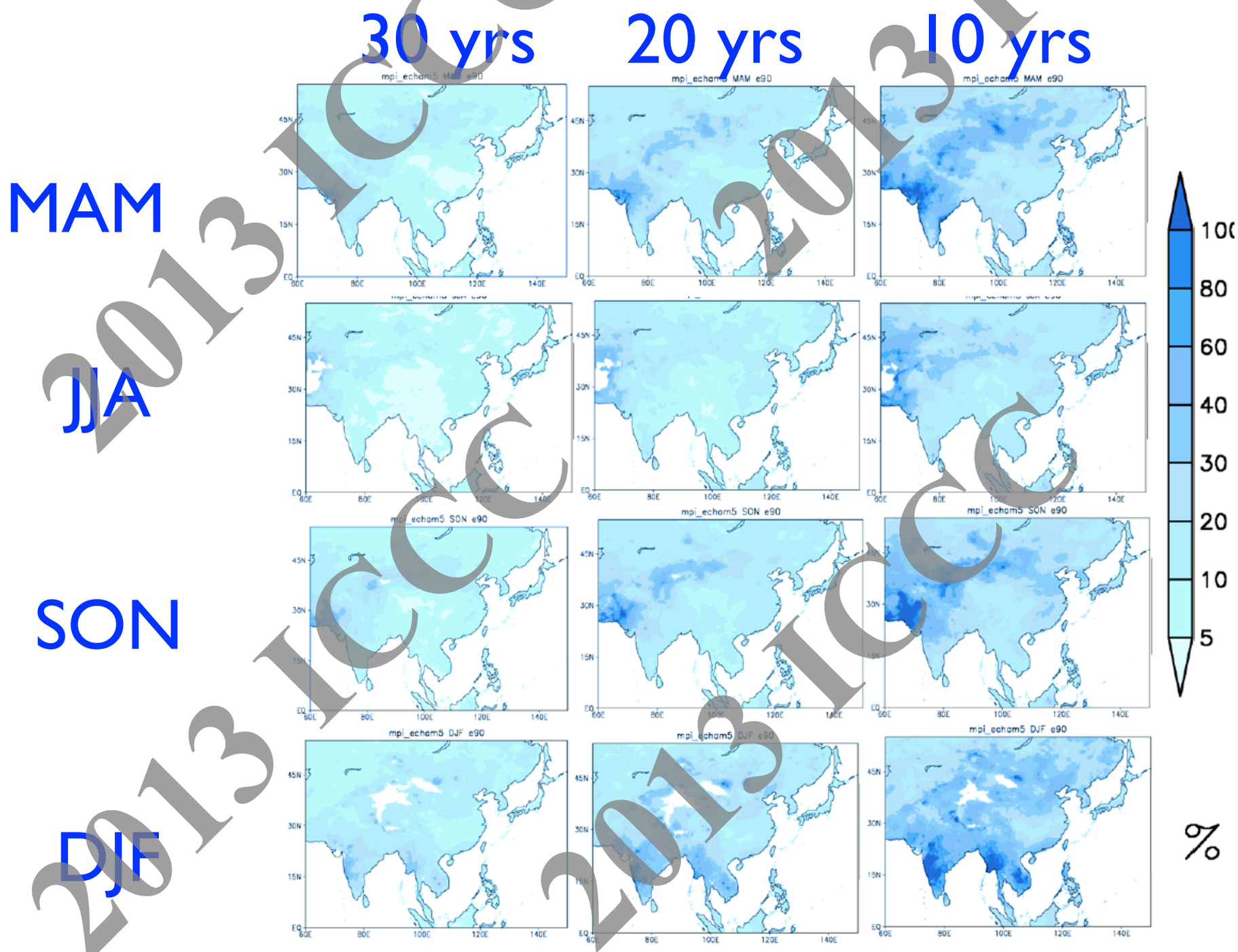
Name	Domain	Resolution	Period
Monsoon Asia (MA)	60°E-150°E, 15°S-55°N	0.5° and 0.25°, daily	1951-2007
Middle East (ME)	15°E-65°E, 25°N-45°N		
Russia (RU)	15°E-165°W, 34°N-84°N		

Validation

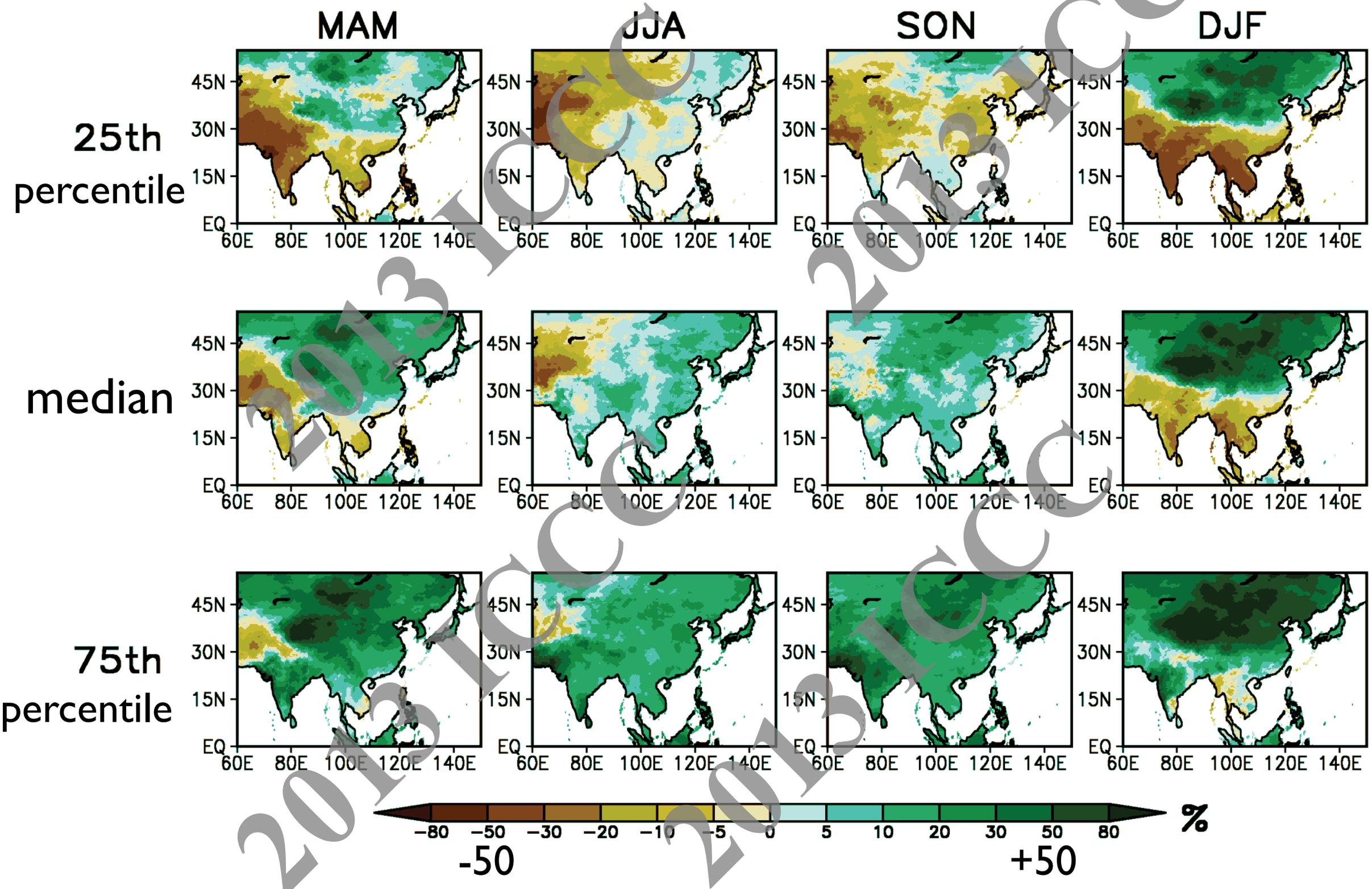
- Bias corrected and downscaled of current climate using APHRODITE rainfall analysis



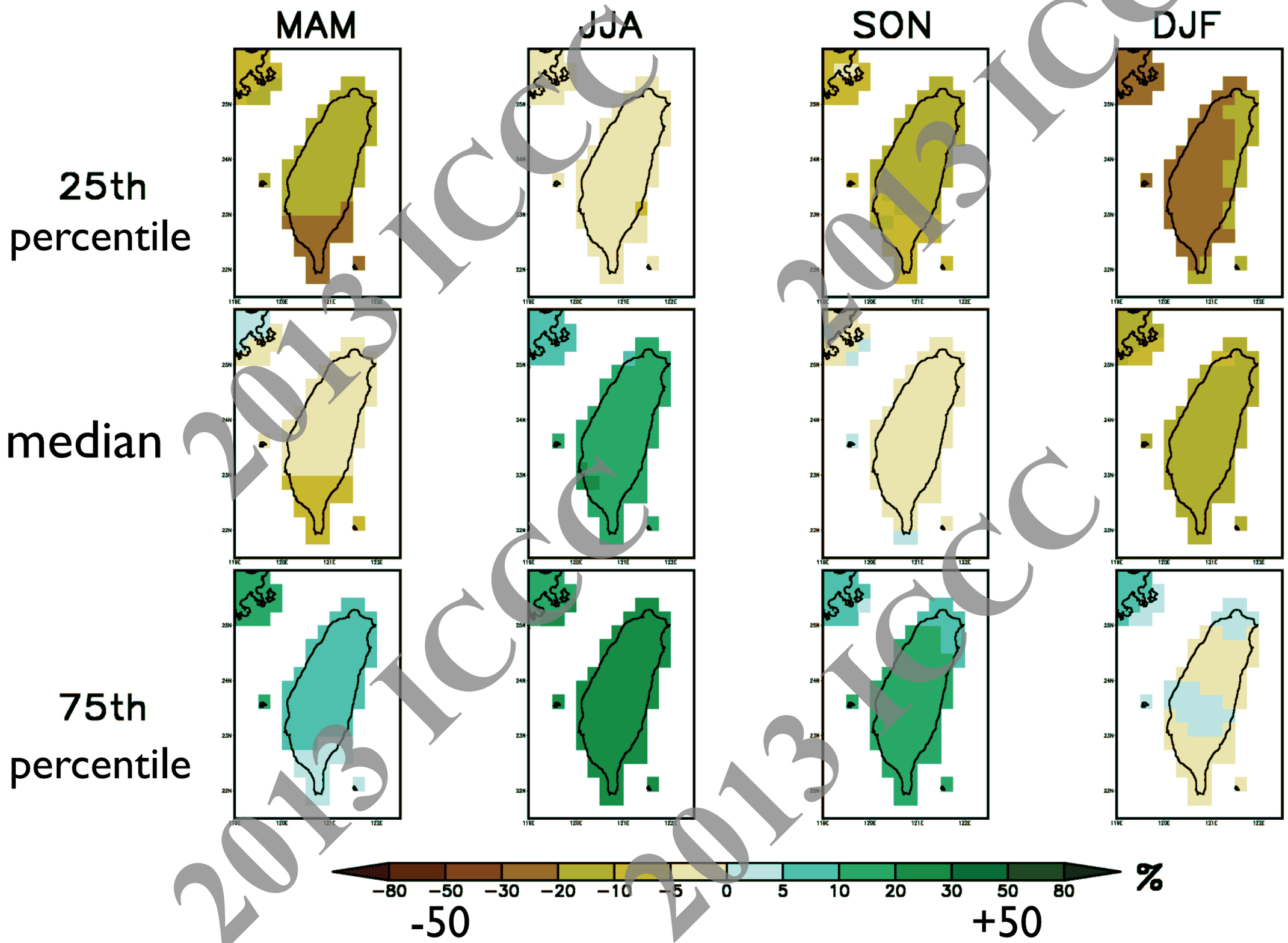
- 90th percentile of downscaled error estimate from bootstrapping 10, 20, or 30 out of 40 years data from present climate
- Typically less than 20% error with regional monthly rainfall more than 1 mm/day (20 years sample)



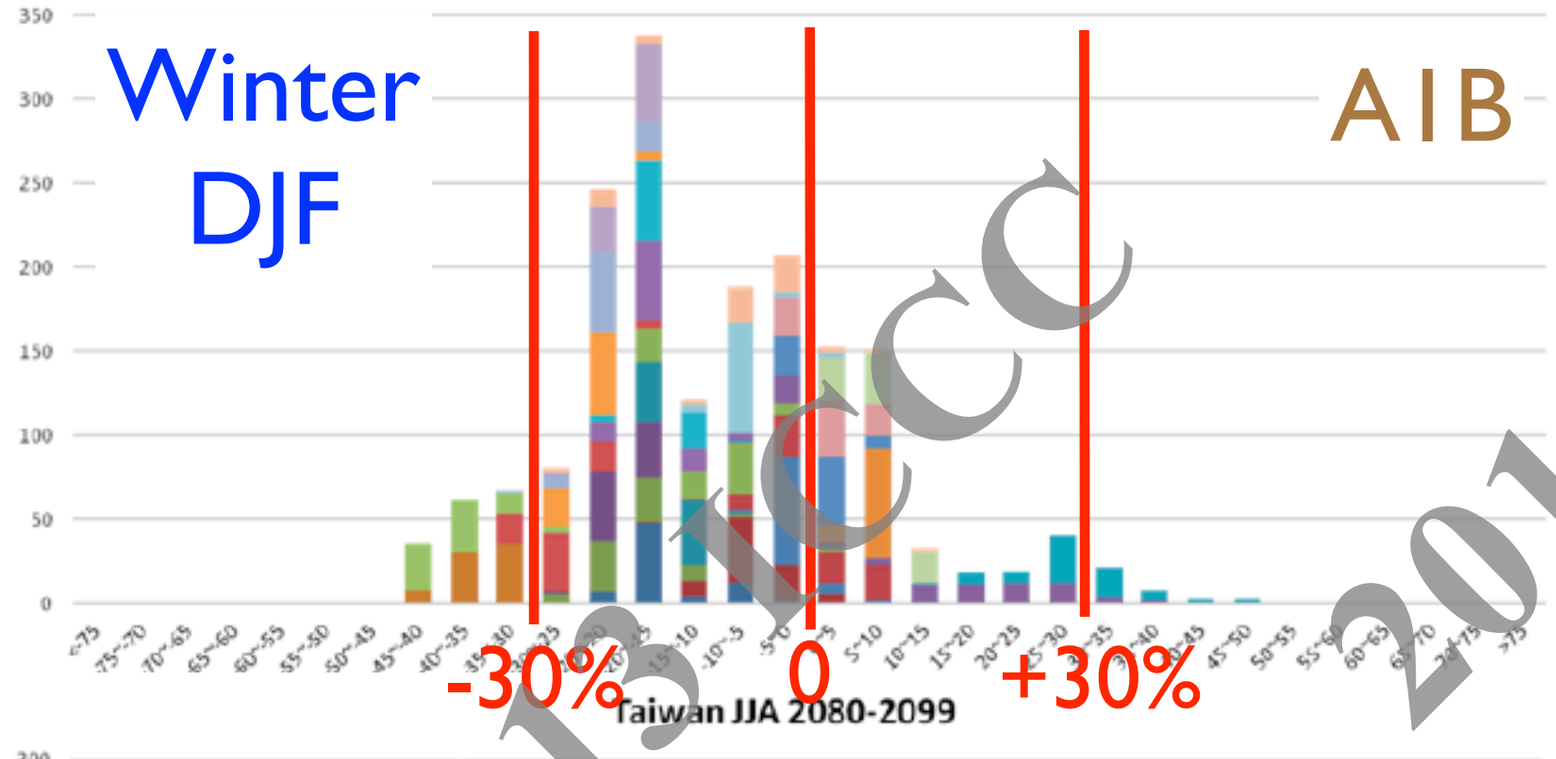
CMIP3 Model Projected Future Change in Precipitation (%) A1B



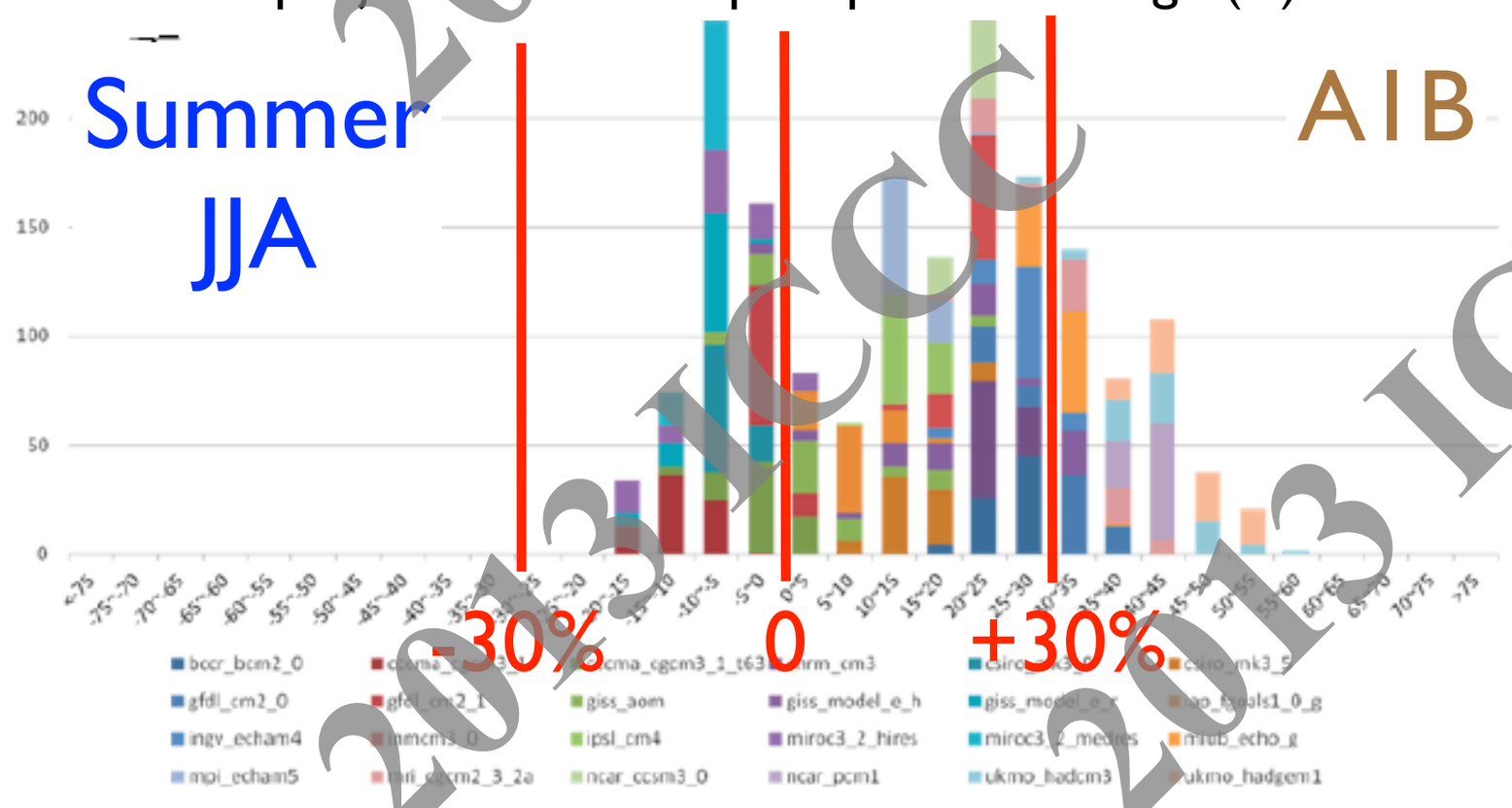
CMIP3 Model Projected Future Change in Precipitation (%) A1B



2080-2099 projected winter precipitation change (%) in Taiwan

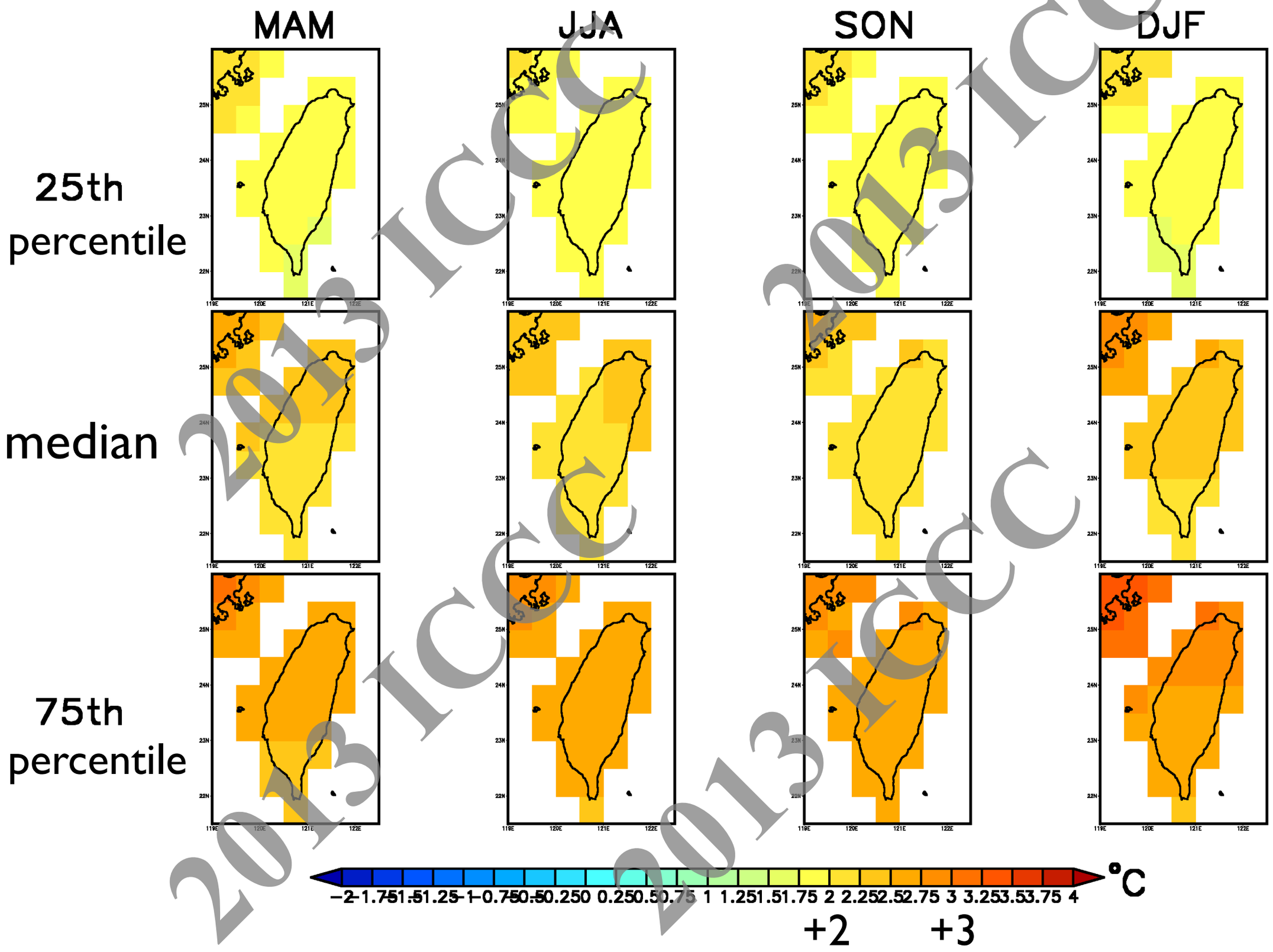


2080-2099 projected summer precipitation change (%) in Taiwan

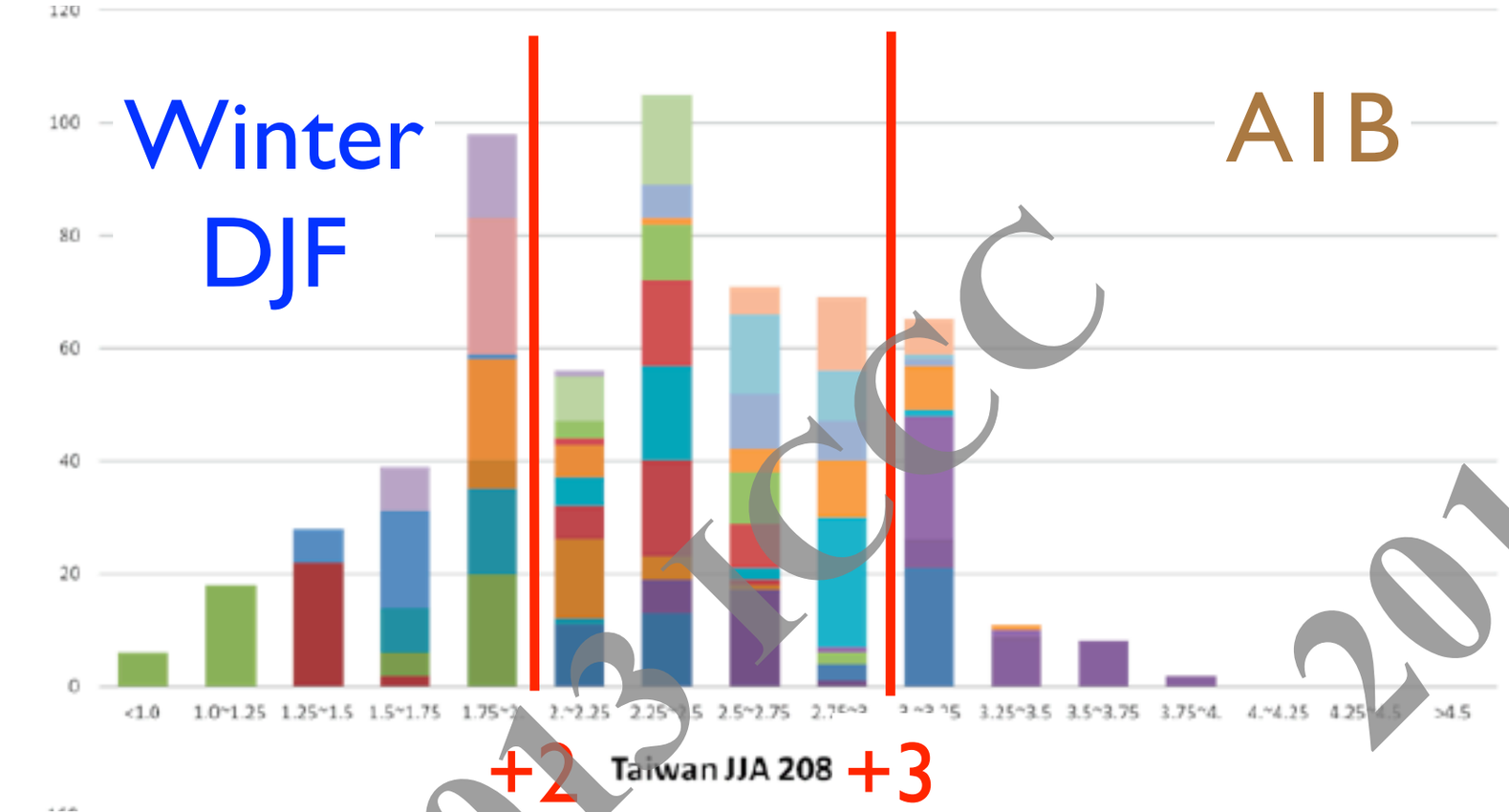


- One can also focus on area of interests and construct PDF for projected future precipitation change from all models (Taiwan: 75 grids x 24 models)
- Ensemble of opportunity (probability)

CMIP3 Model Projected Future Change in Temperature (°C) A1B



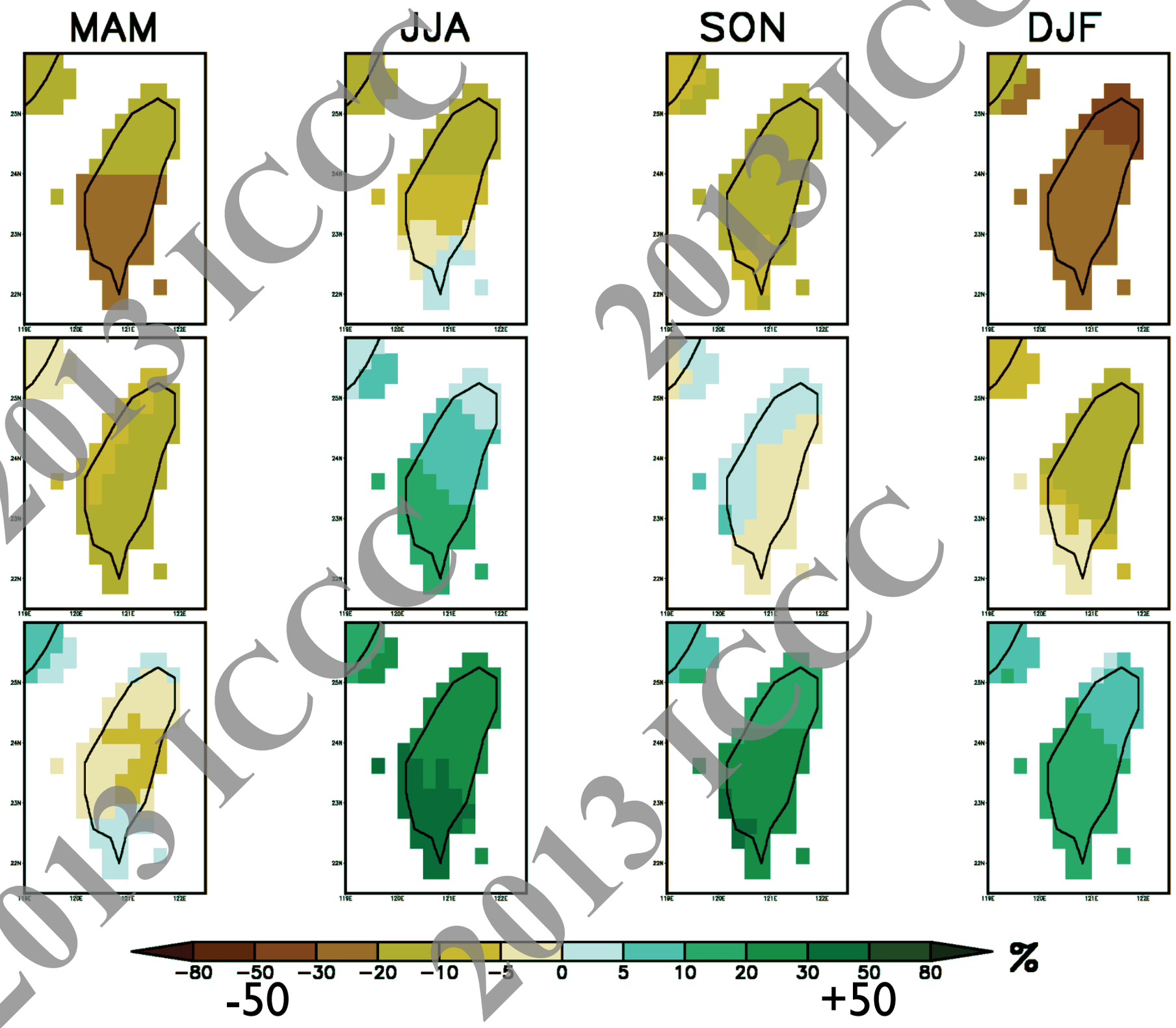
2080-2099 projected winter temperature change (°C) in Taiwan



2080-2099 projected summer temperature change (°C) in Taiwan

- One can also focus on area of interests and construct PDF for projected future temperature change from all models (Taiwan: 75 grids x 24 models)
- Ensemble of opportunity (probability)

CMIP5 Model Projected Future Change in Precipitation (%) RCP85



CMIP5 RCP85

CMIP3 AIB

JJA

DJF

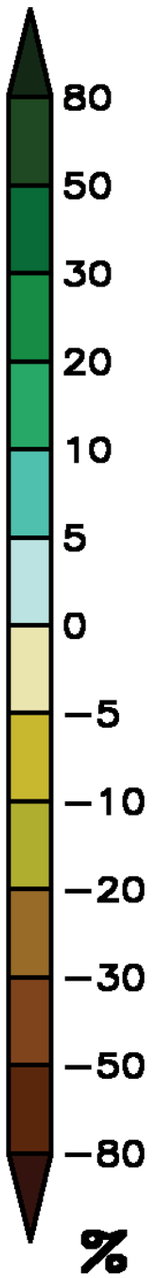
JJA

DJF

25 percentile

median

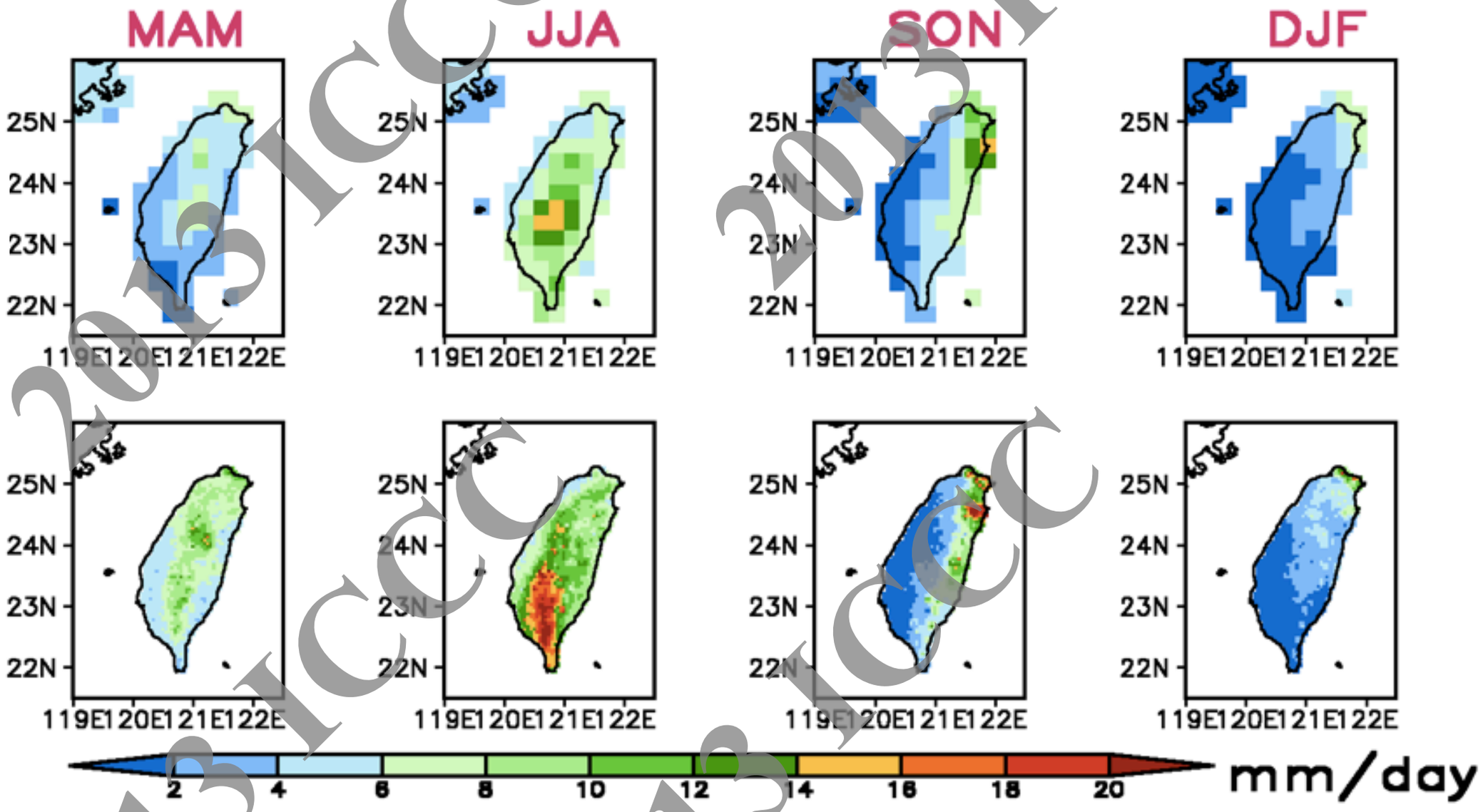
75 percentile



Taiwan 5km gridded rainfall better resolved local rainfall characteristics

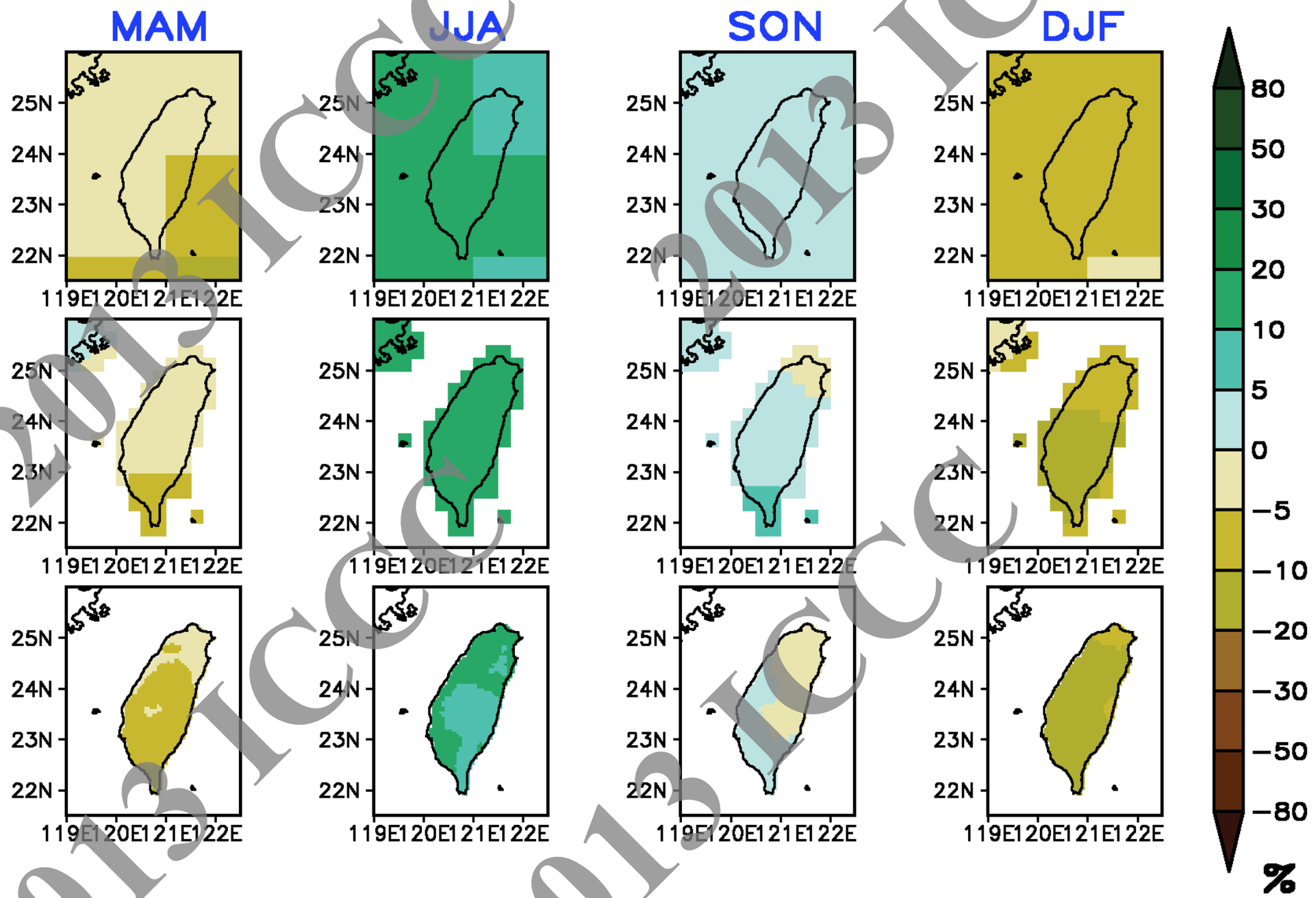
Aphrodite 0.25°

Taiwan gridded 5km

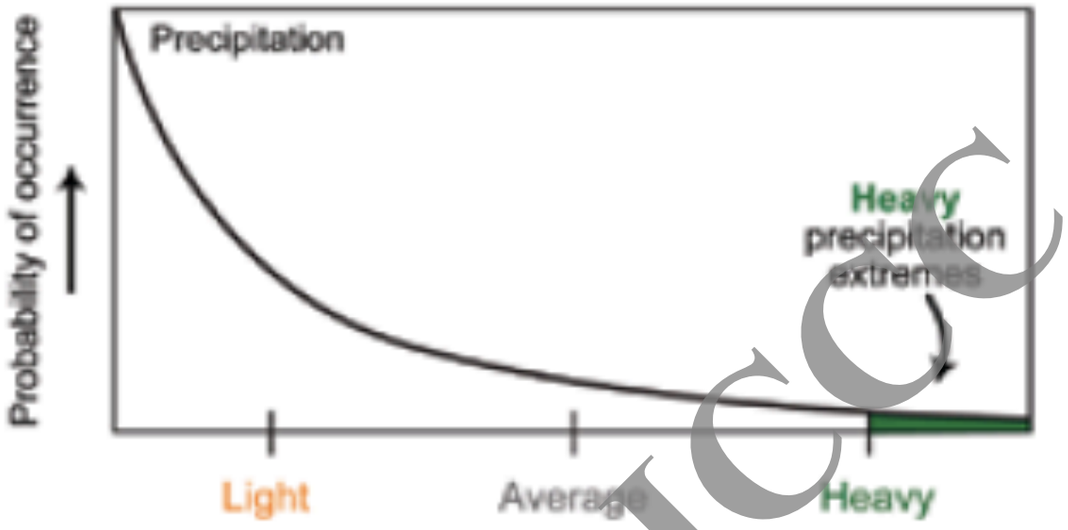


CMIP3 Model Projected Future Change in Precipitation (%) A1B

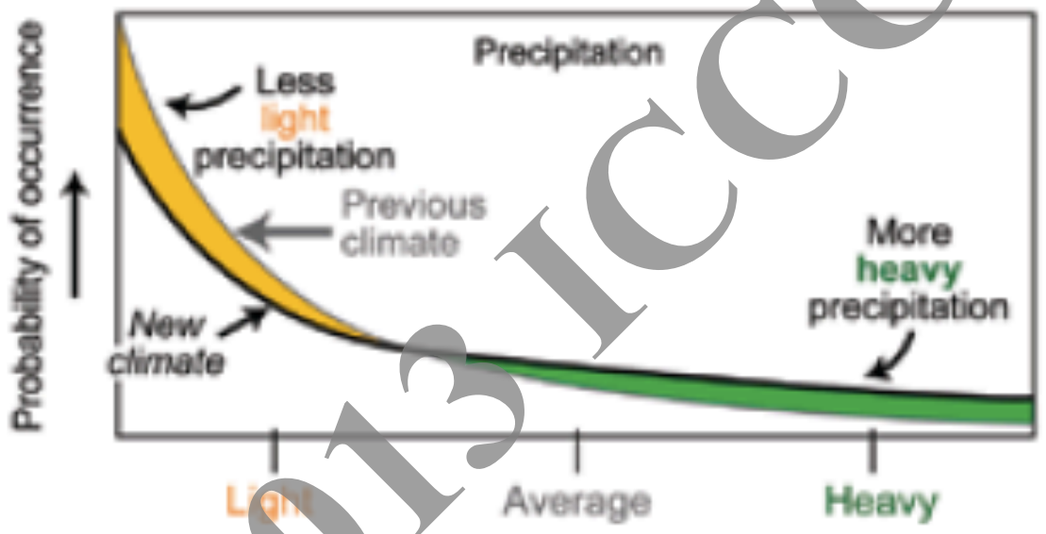
Model Resolution



What is extreme?

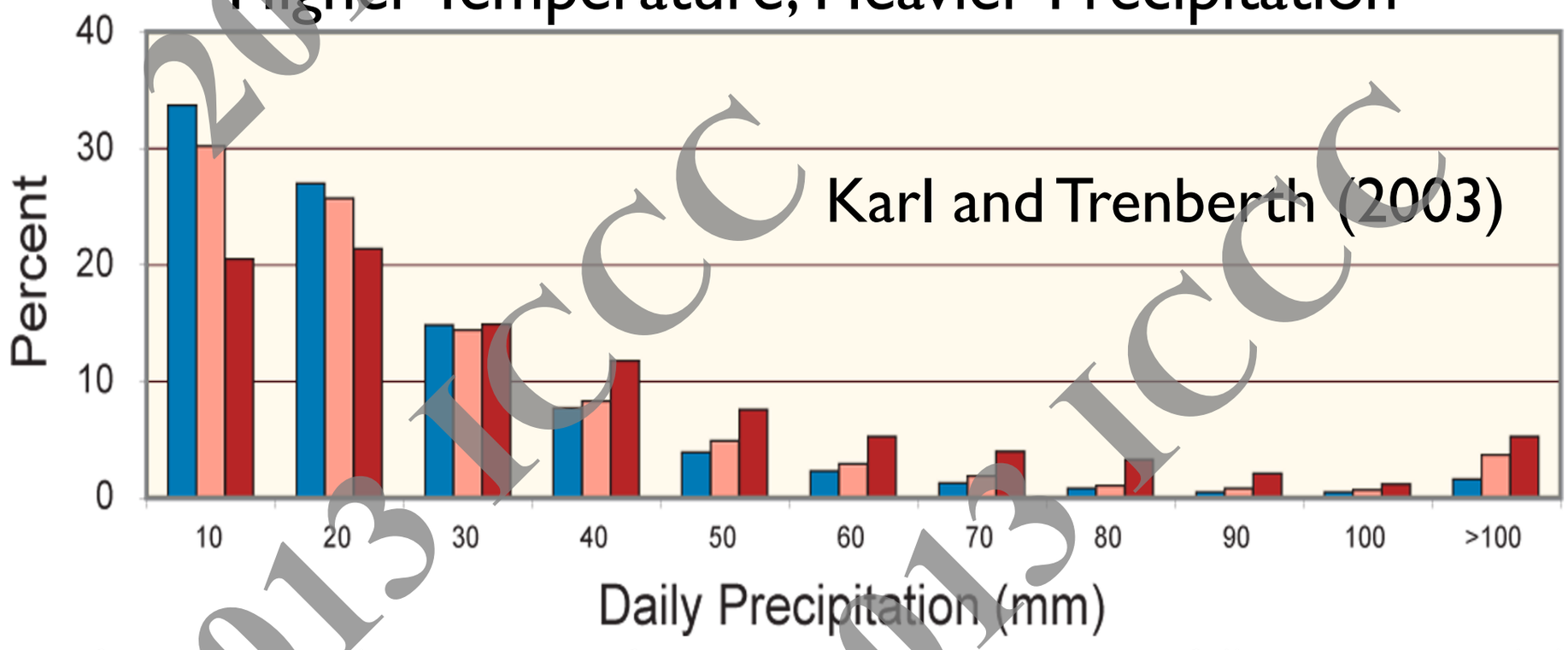


Change in probability of extremes



US Climate Change Science Program (2008)

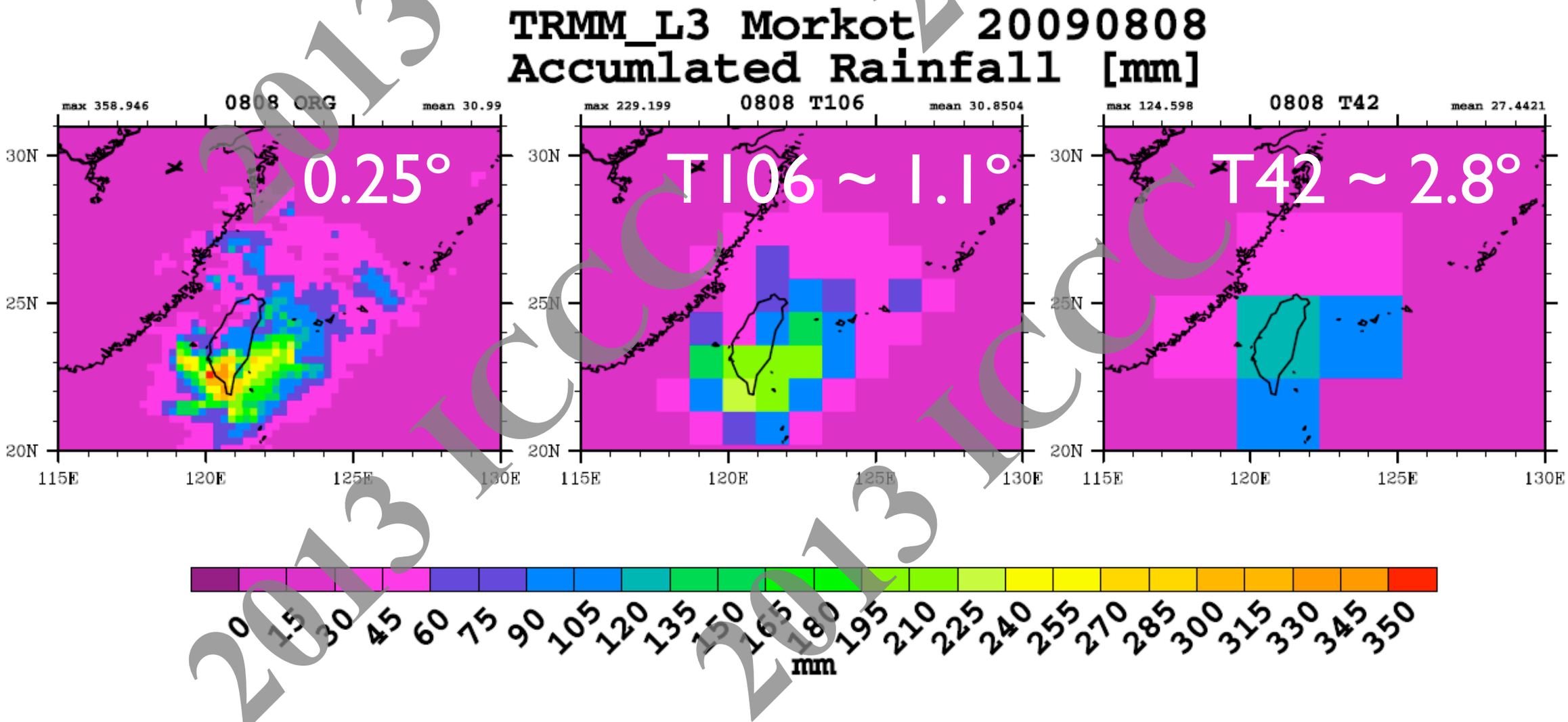
Higher Temperature, Heavier Precipitation



Percent of total seasonal precipitation for stations with 230mm±5mm falling into 10mm daily intervals based on seasonal mean temperature. Blue bar -3°C to 19°C, pink bar 19°C to 29°C, dark red bar 29°C to 35°C, based on 51, 37 and 12 stations

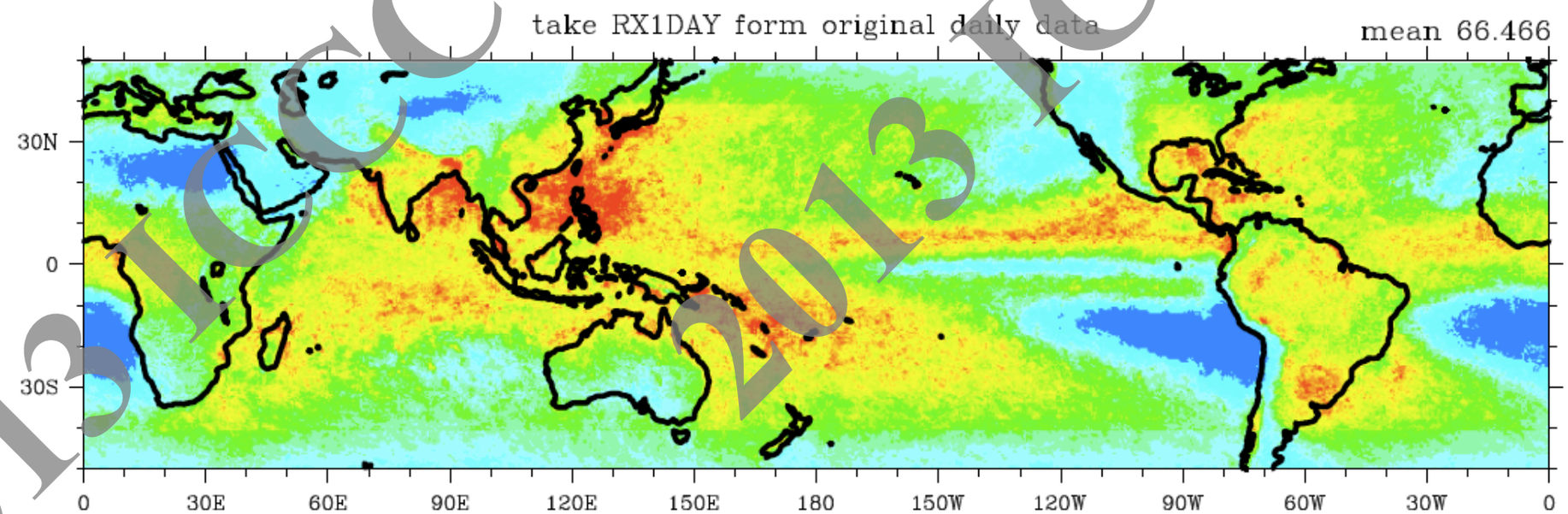
Statistical downscaling for the extremes?

High resolution observed daily rainfall analysis
regrid to typical model resolution

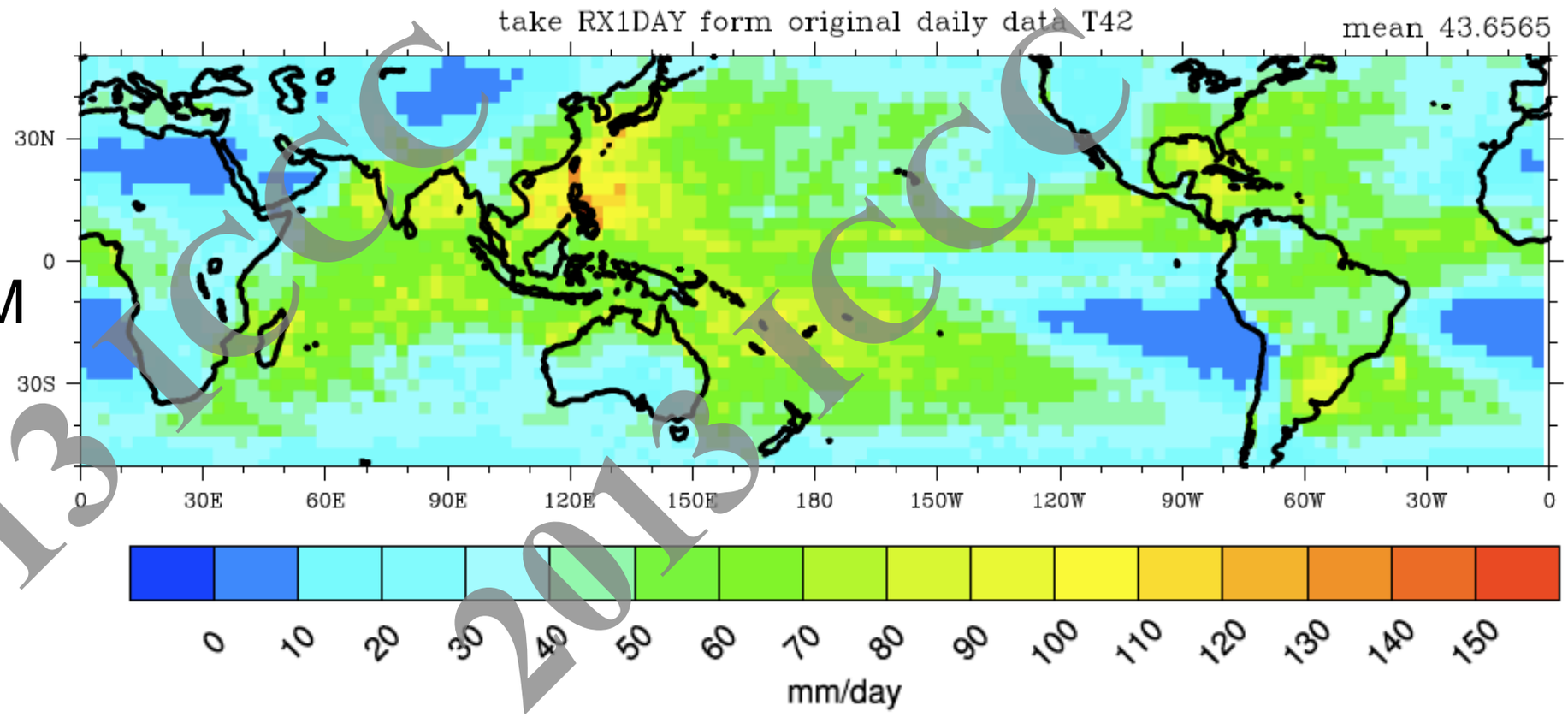


Deriving high-impact weather extremes at different spatial resolutions using observational estimates

Annual maximum daily rainfall (Rx1day) at 0.25° resolution derived from TRMM (1998-2009)

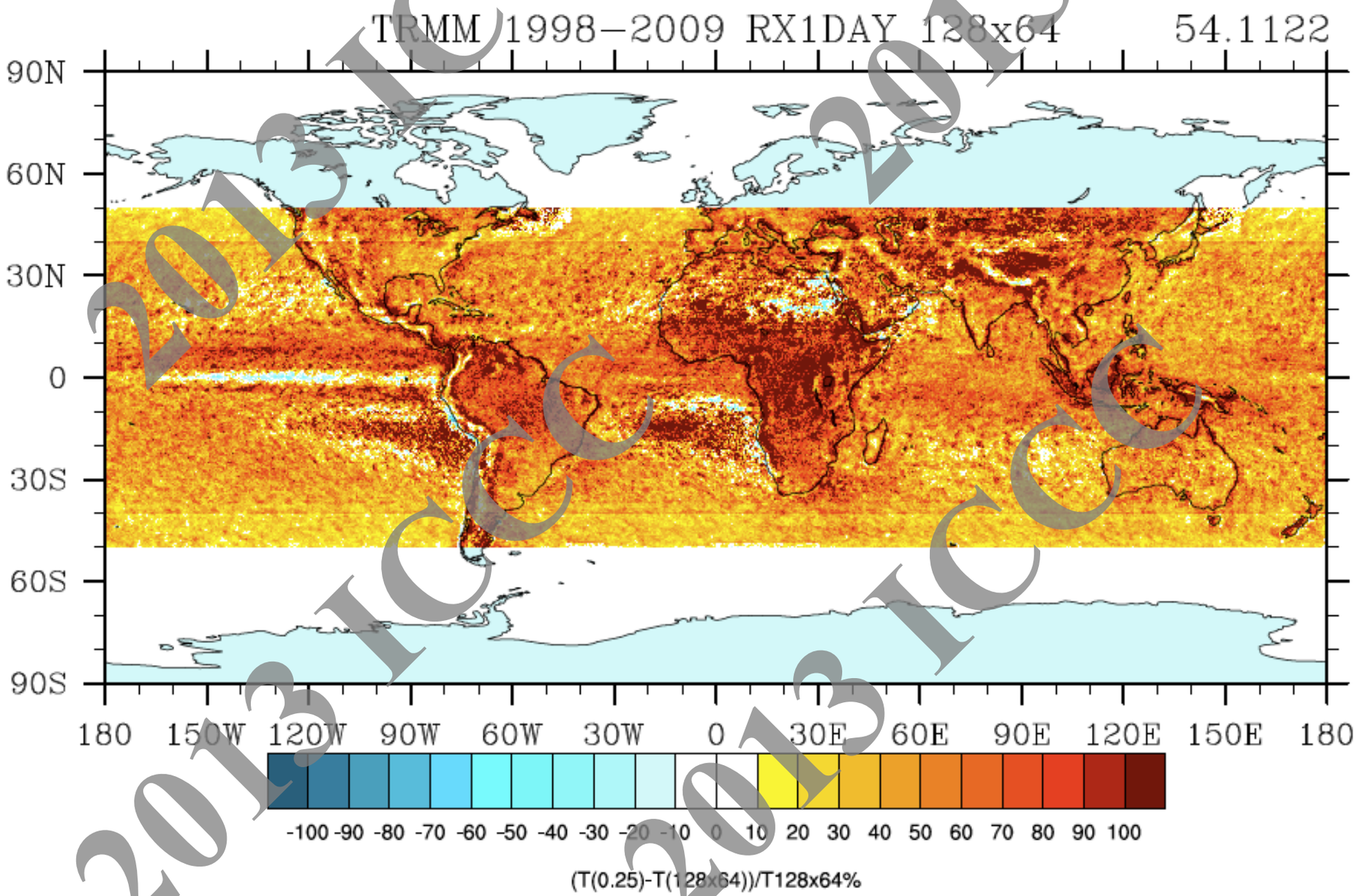


Annual maximum daily rainfall (Rx1day) at T42 derived from TRMM



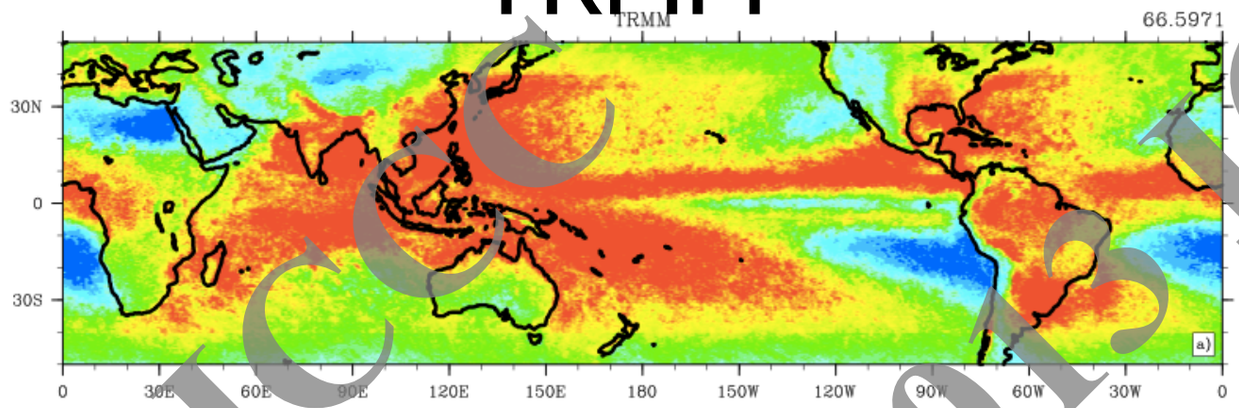
Correct the Spatial Scale Dependence of high-impact weather extremes using observational estimates

Enhancing factor (%) from T42 to 0.25° resolution [P(0.25°)-P(T42)]/P(T42)

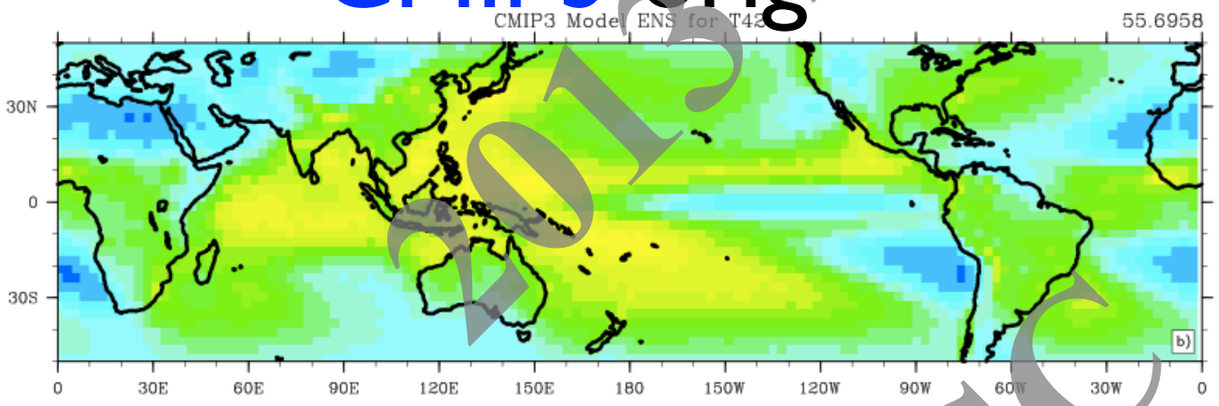


Downscaled model ensemble mean RX1day

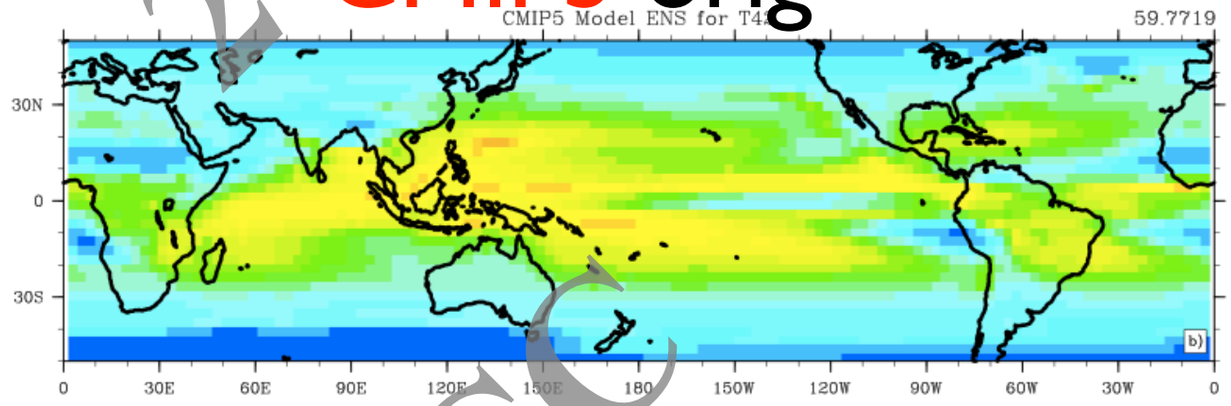
TRMM



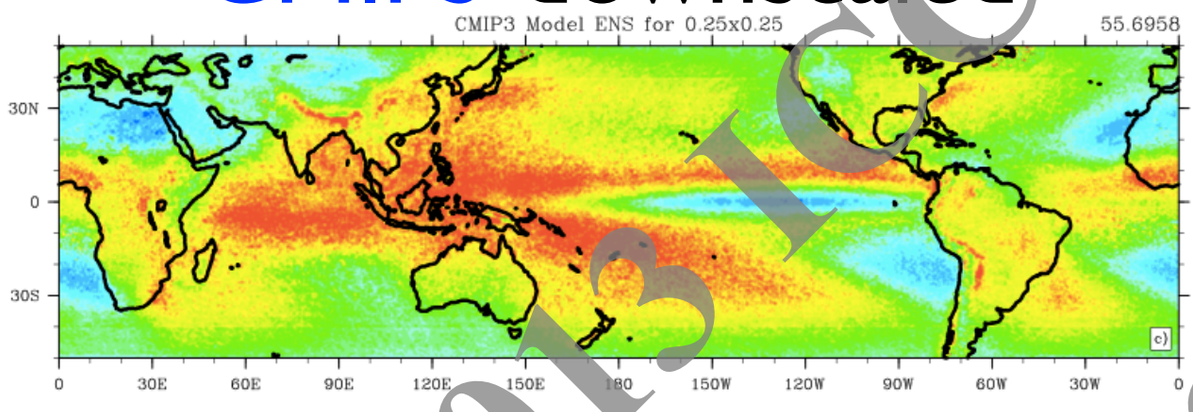
CMIP3 orig



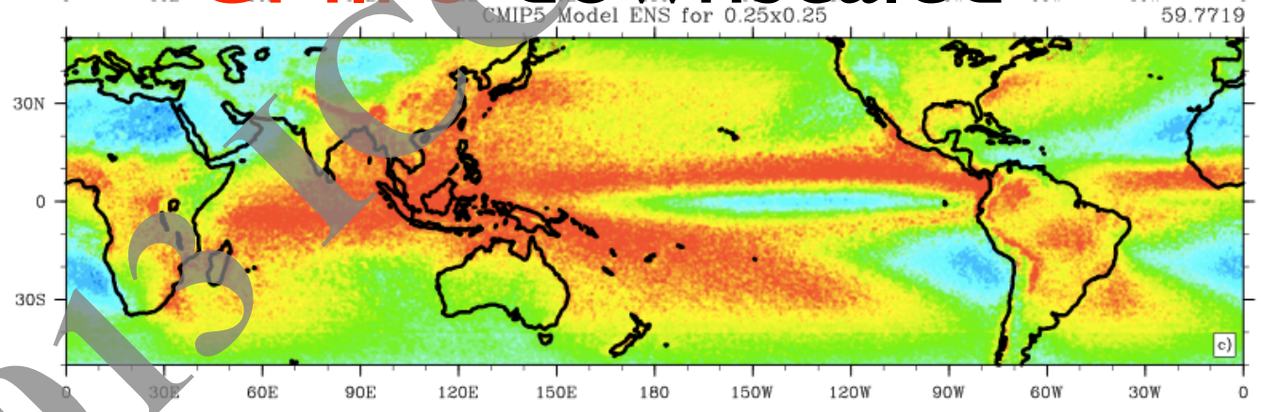
CMIP5 orig



CMIP3 downscaled



CMIP5 downscaled



OBS

A

remap

C

rx1day

rx1day

D

remap

E

B

$$\Delta R_i = \frac{B_i}{E_i}$$

Model

α

Bias correction

rx1day

β

γ

remap

δ

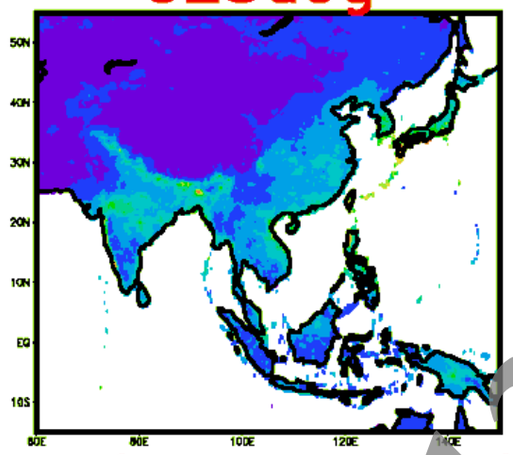
ε

$$\varepsilon_i = \delta_i \times \Delta R_i$$

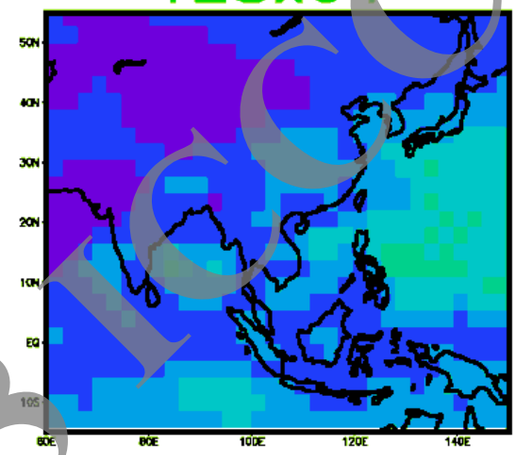
(1961-2000)

rx1day mri_cgcm2_3_2a

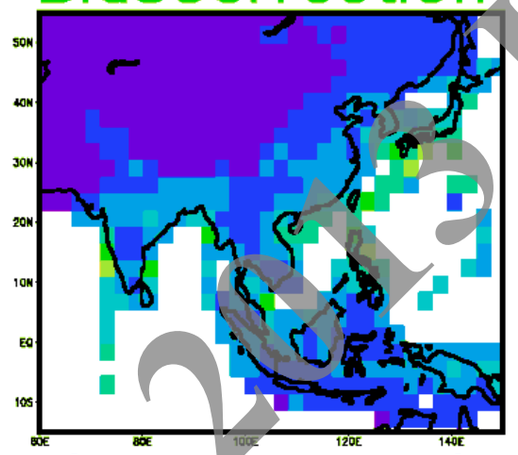
obs(1980~1999)
025deg



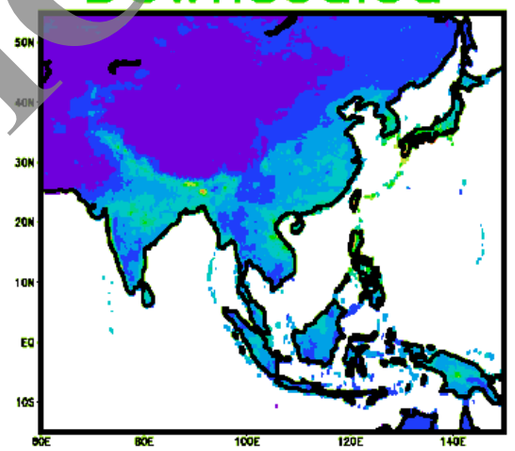
128x64



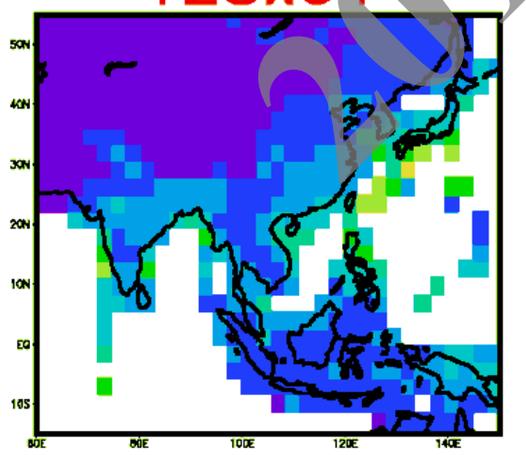
20c3m(1980~1999)
BiasCorrection



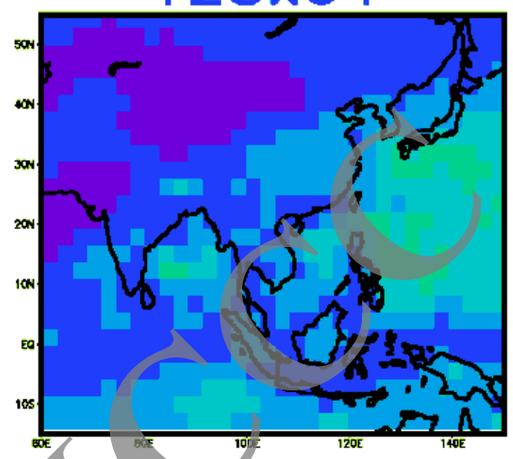
Downscaled



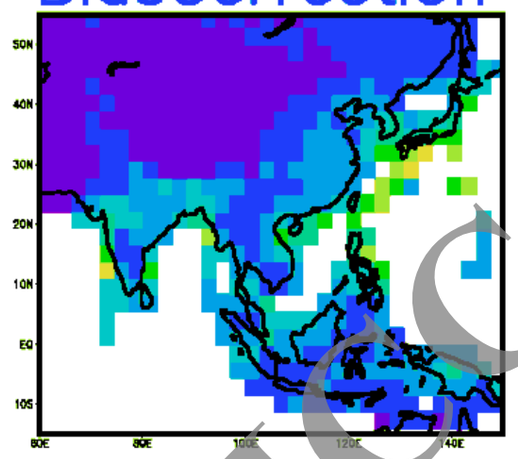
obs(1980~1999)
128x64



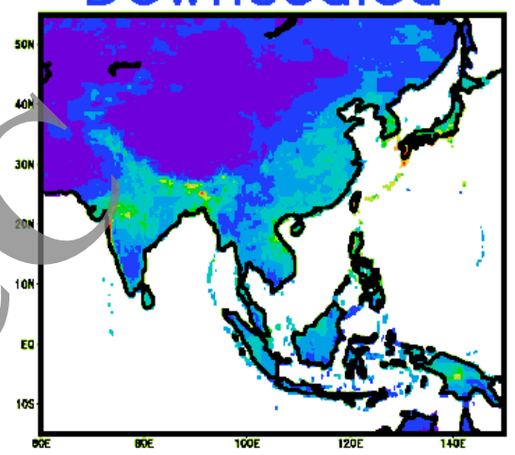
128x64

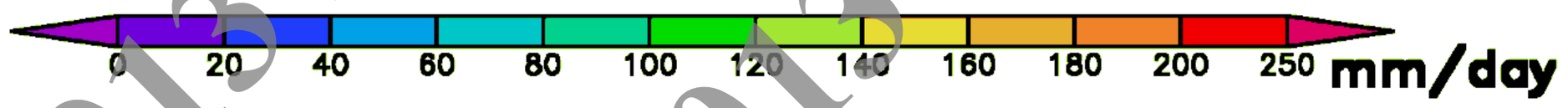


a1b(2080~2099)
BiasCorrection

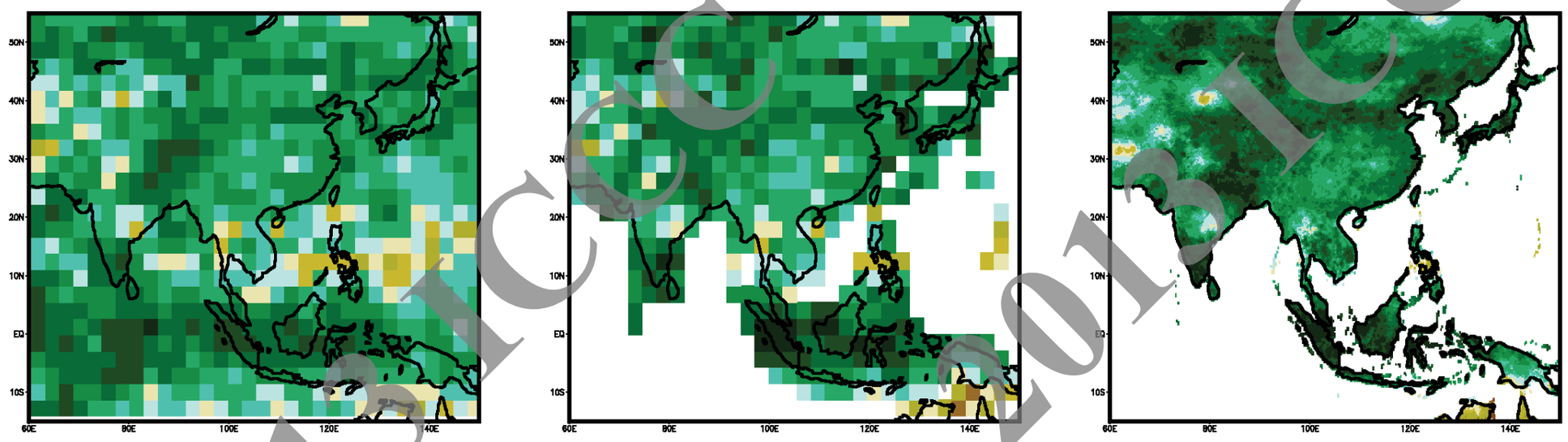


Downscaled





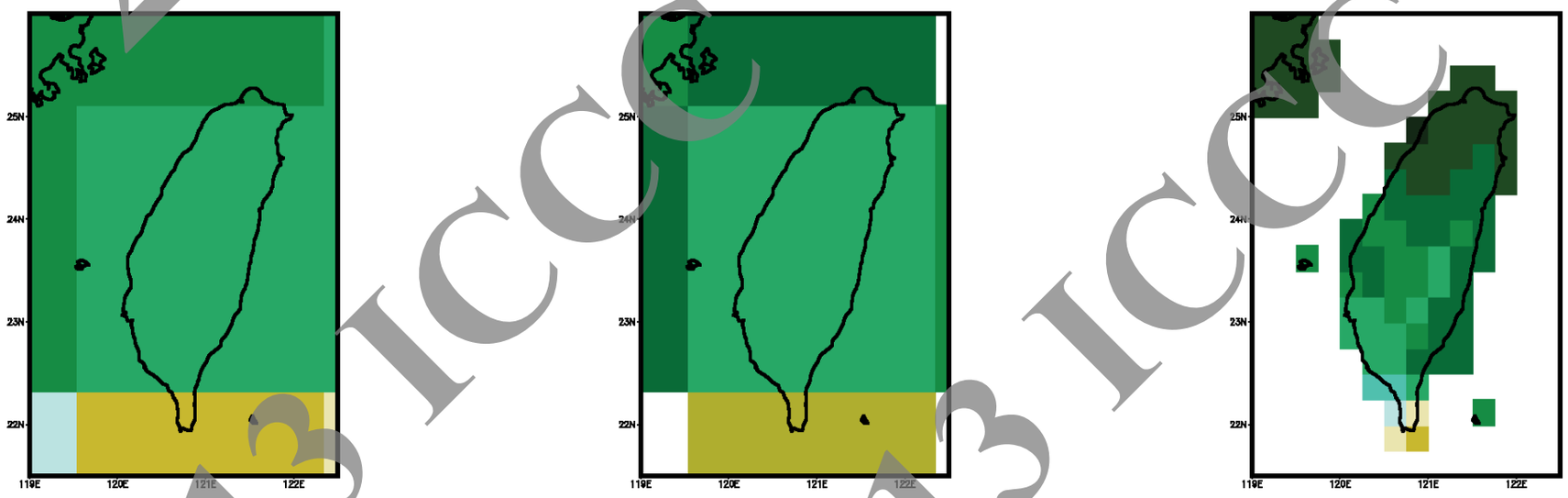
miroc3_2_medres rx1day Change (%)

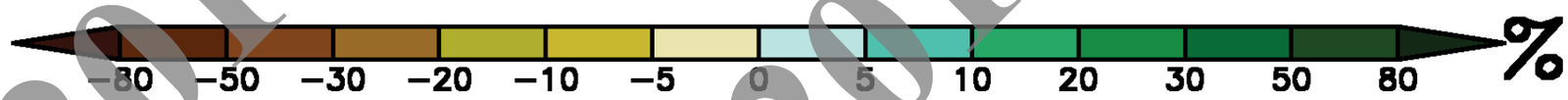


Original
128x64

BiasCorrection
128x64

Downscaled
025deg

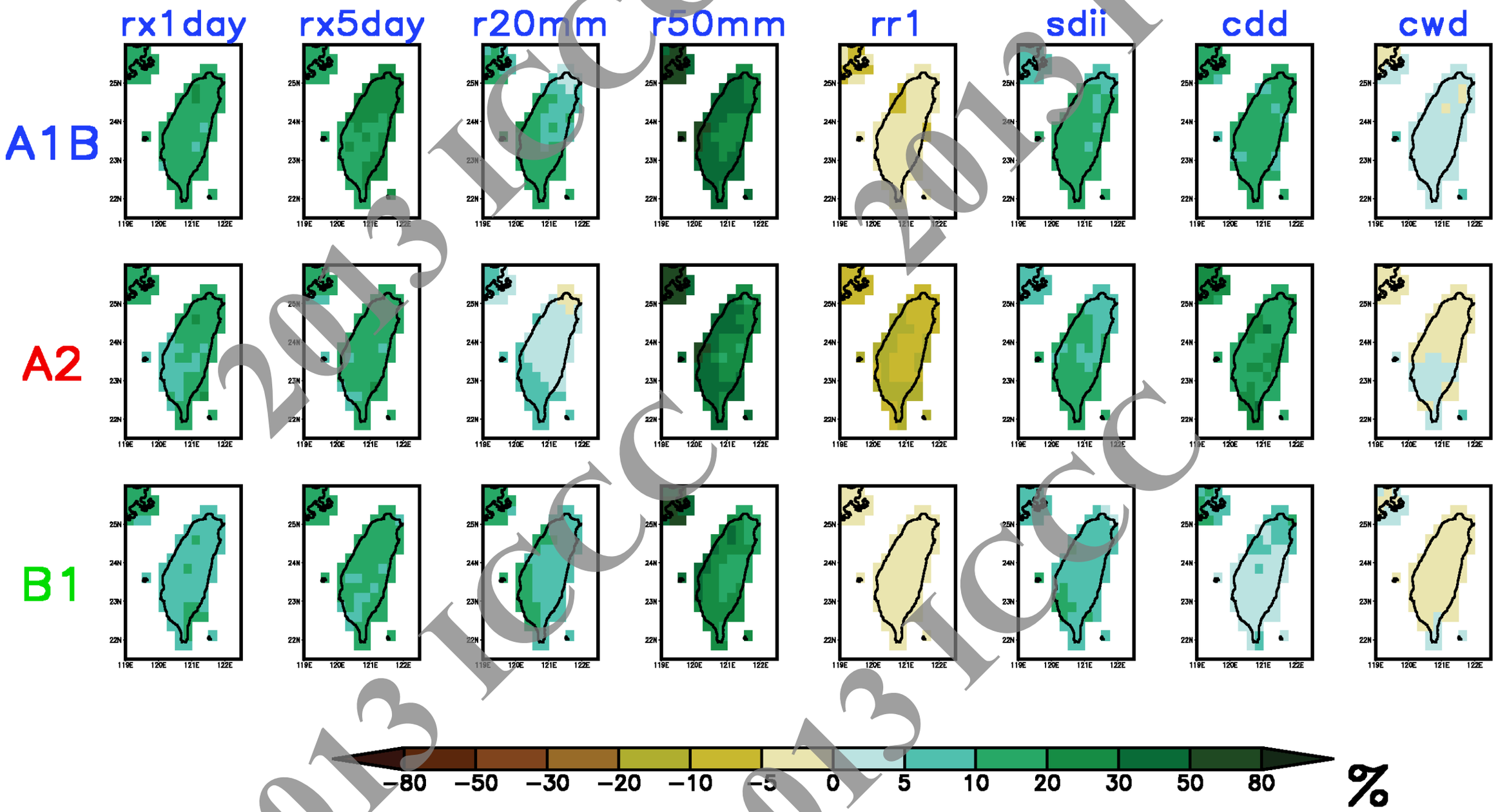




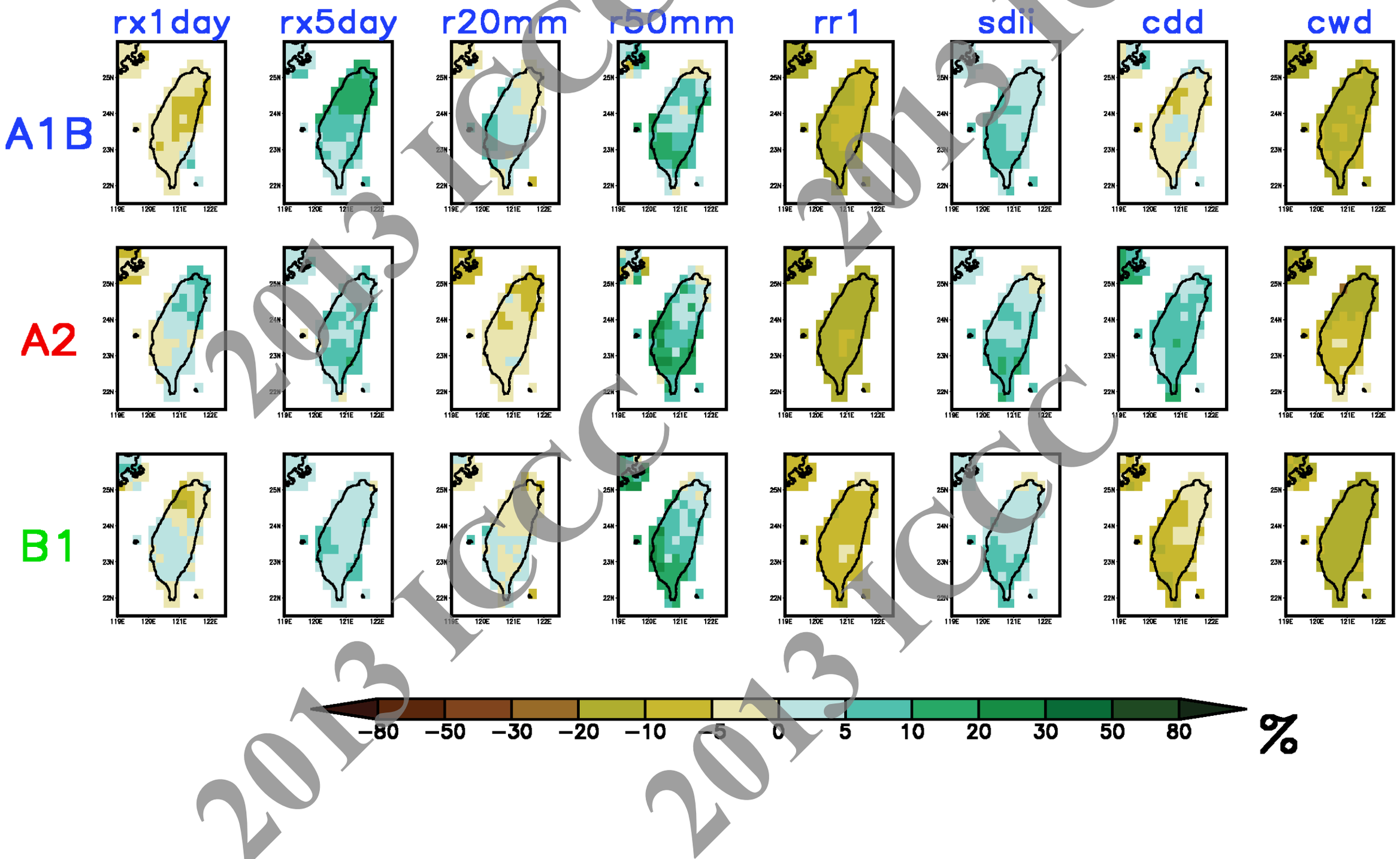
Extreme Indices

		unit
RX1DAY	Highest one day precipitation amount per time period	mm/day
RX5DAY	Highest five-day precipitation amount per time period	mm/day
R20MM	Heavy precipitation days index per time period	day
R50MM	Very heavy precipitation days index per time period	day
RR1	Wet days index per time period (RR>1mm)	day
SDII	Simple daily intensity index per time period (RR>1)	mm/day
CDD	Consecutive dry days index per time period	day
CWD	Consecutive wet days index per time period	day

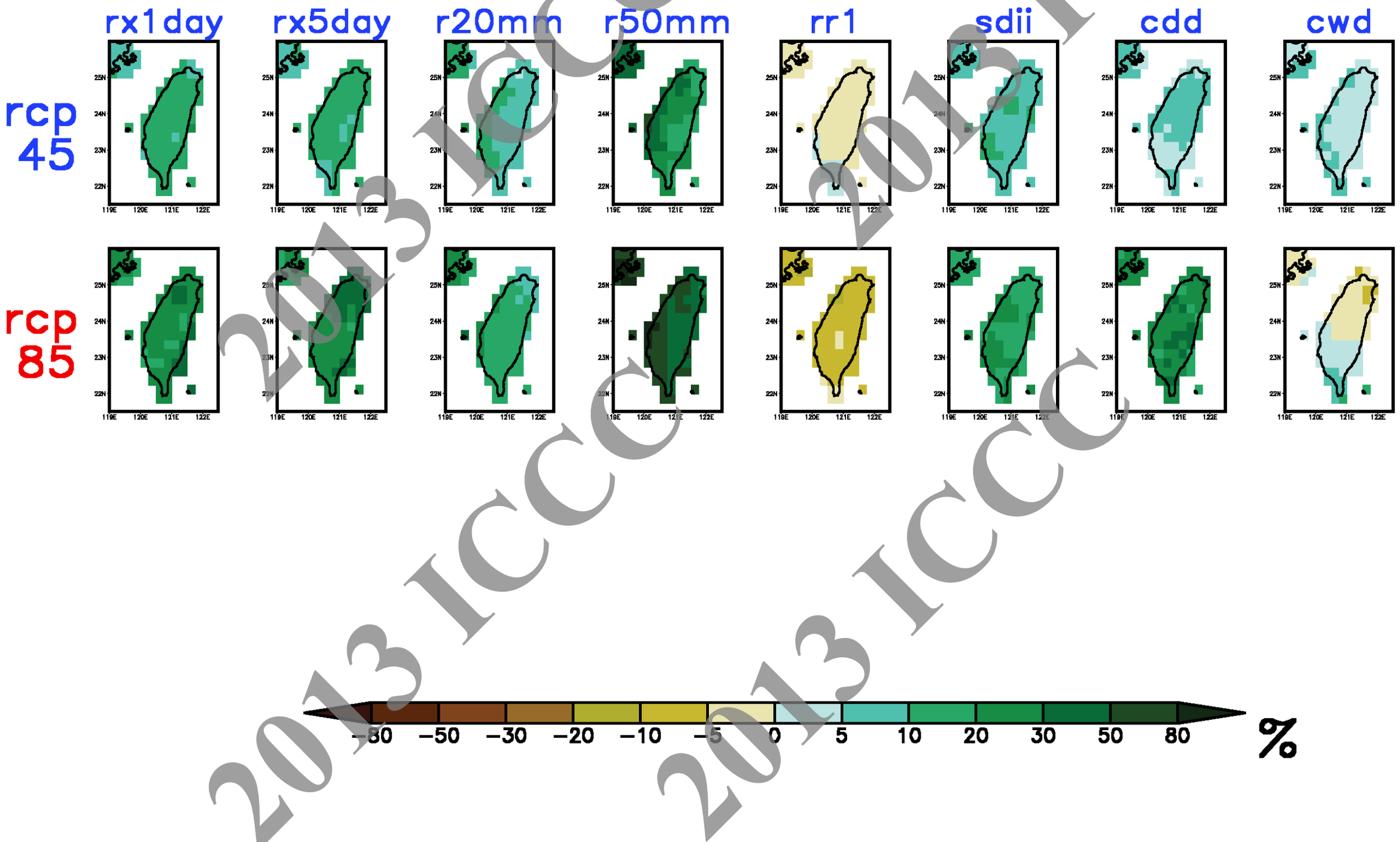
CMIP3 Model Ensemble Mean
Projected Future Change in Extreme Climate Indices (%)



CMIP3 Model Ensemble 25 percentile
Projected Future Change in Extreme Climate Indices (%)



CMIP5 Model Ensemble Mean
Projected Future Change in Extreme Climate Indices (%)



成果與應用說明

- 對於未來氣候變遷推估，不管是全球或區域尺度，應該涵蓋科學上已知的不確定性，並忠實地評估推估或區域細節降尺度方法所可能伴隨的誤差。
- 現階段，統計降尺度是一種比較容易涵蓋推估不確定性的方式，但是必須同時瞭解這些方法的的假設與應用上的限制。
- 統計降尺度不僅可以運用在平均氣候變遷推估，也可以用在極端天氣與氣候指標的變化推估。
- 目前計畫平台的統計降尺度可以提供台灣地區未來氣候變遷推估區域細節的機率分佈，並且與IPCC報告中的區域推估機率分佈有一致性，並且已修正模式誤差，有利台灣地區氣候變遷影響調適的研究。
- 必須小心的是，這些以IPCC報告所使用的氣候模式所做的推估機率分佈，並不能排除氣候模式可能的誤差或其無法模擬的現象，也不是最好的涵蓋不確定性的方式，但目前科學家並沒有比氣候模式更好地推估工具。