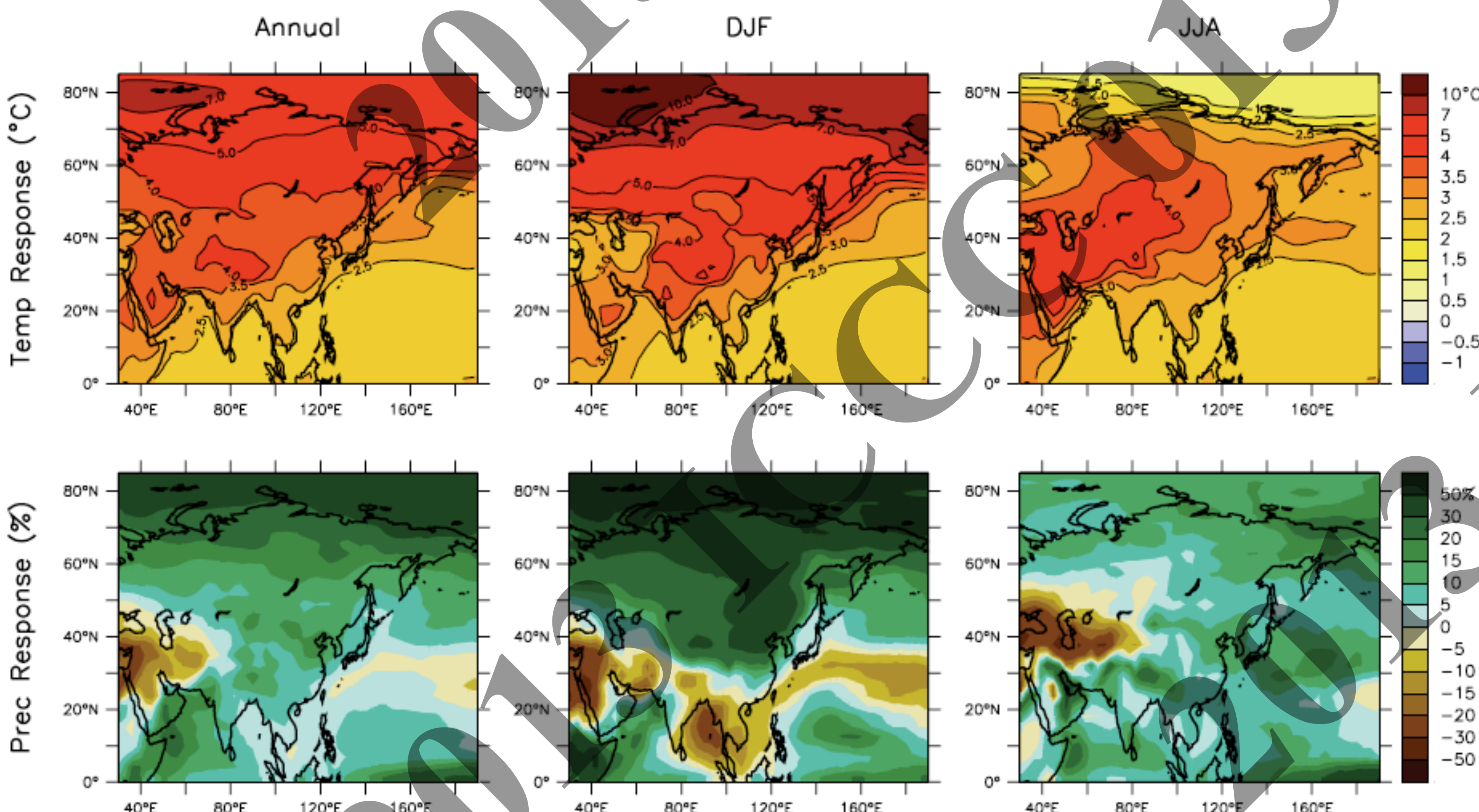
Regionalization of Future Climate Change Projection and Uncertainty Over Taiwan: From Mean Climate States to High-Impact Weather and Climate Extremes

Cheng-Ta Chen and Shou-Li Lin, National Taiwan Normal University, Department of Earth Sciences
NCDR Taiwan Climate Change Projection and Information Platform Project Team

A1B scenario



- Why downscaling?
- How?
- Uncertainty
- Key findings and Limitations

2013 ICCC 2013 ICCC 2013 ICCC 2013 ICCC

Why downscaling?

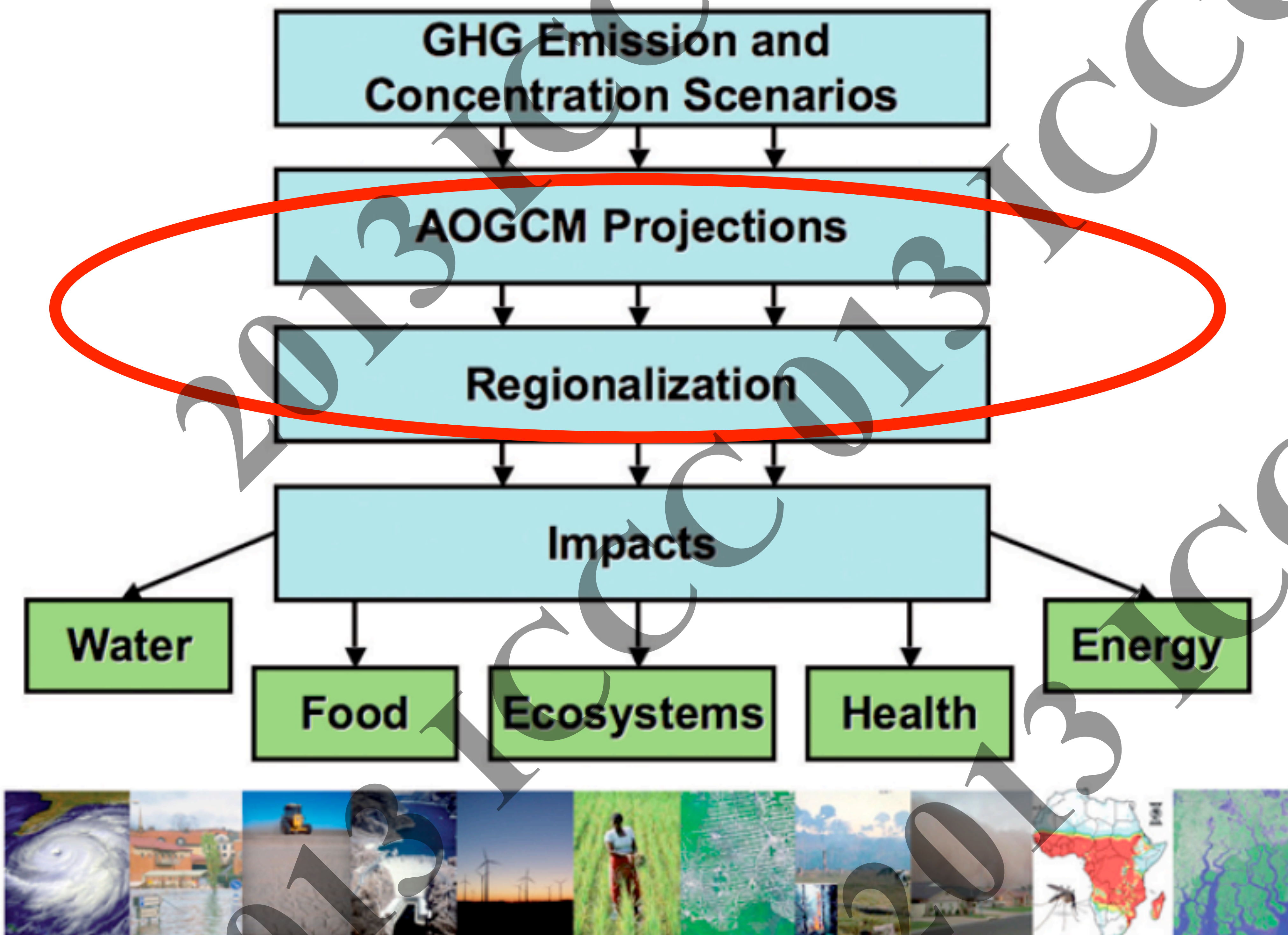


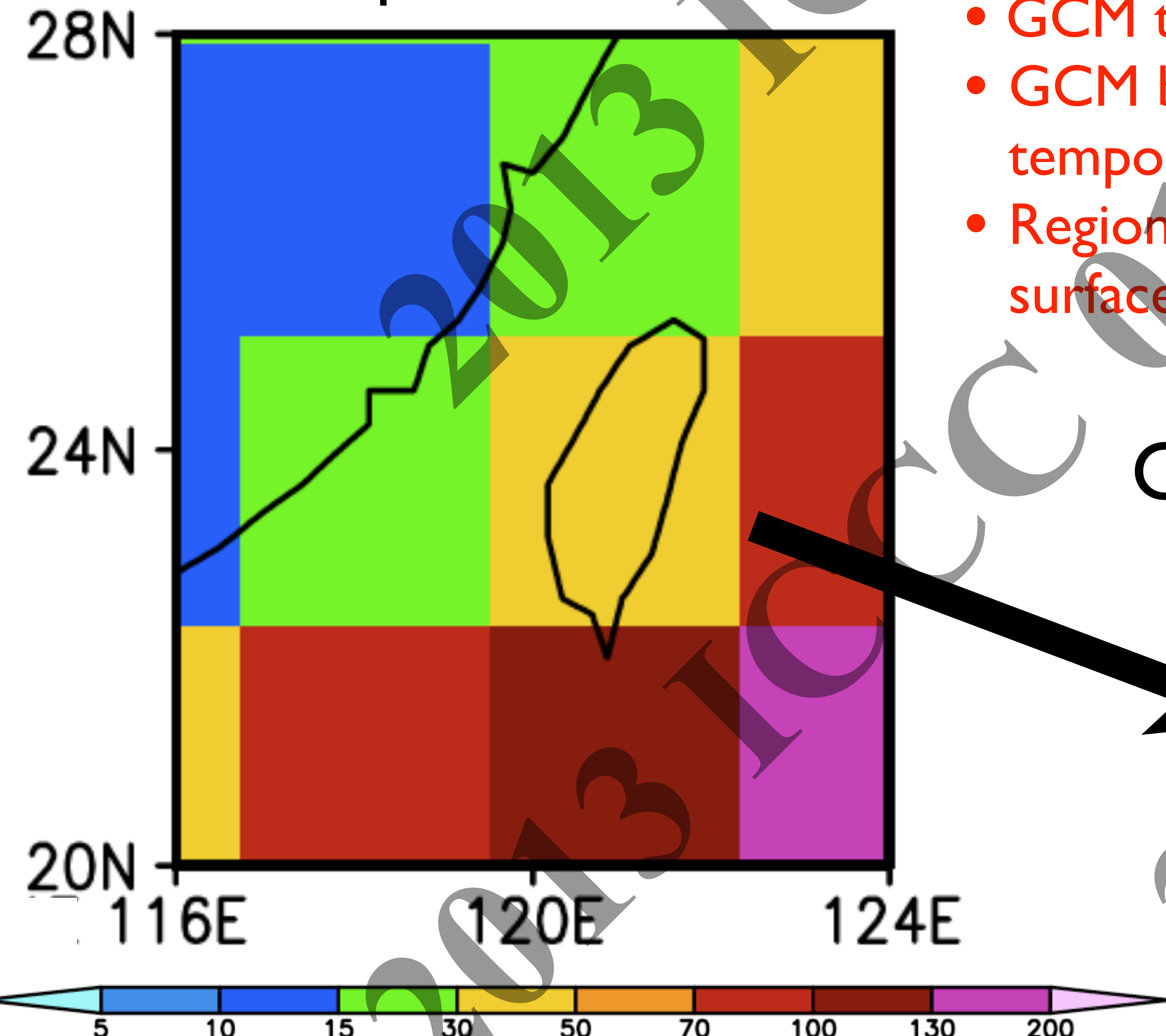
Figure 3 — Schematic depiction of the steps involved in the production of climate change information usable for impact assessment work via regionalization methods

Source: Giorgi (2008)

2013 ICCC 2013 ICCC 2013 ICCC 2013 ICCC

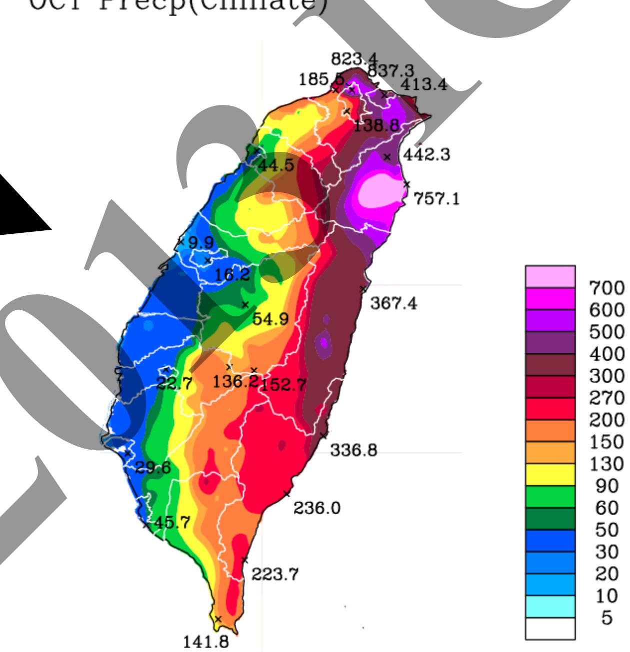
Why downscaling?

GCM (~300 km)
Precipitation October



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

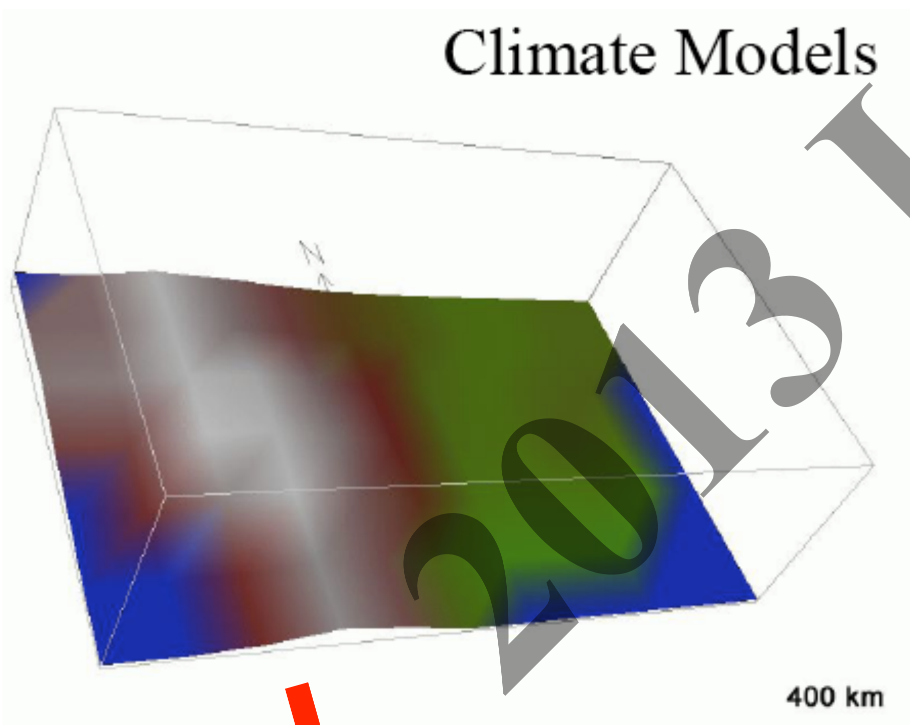
Observation (~5km)

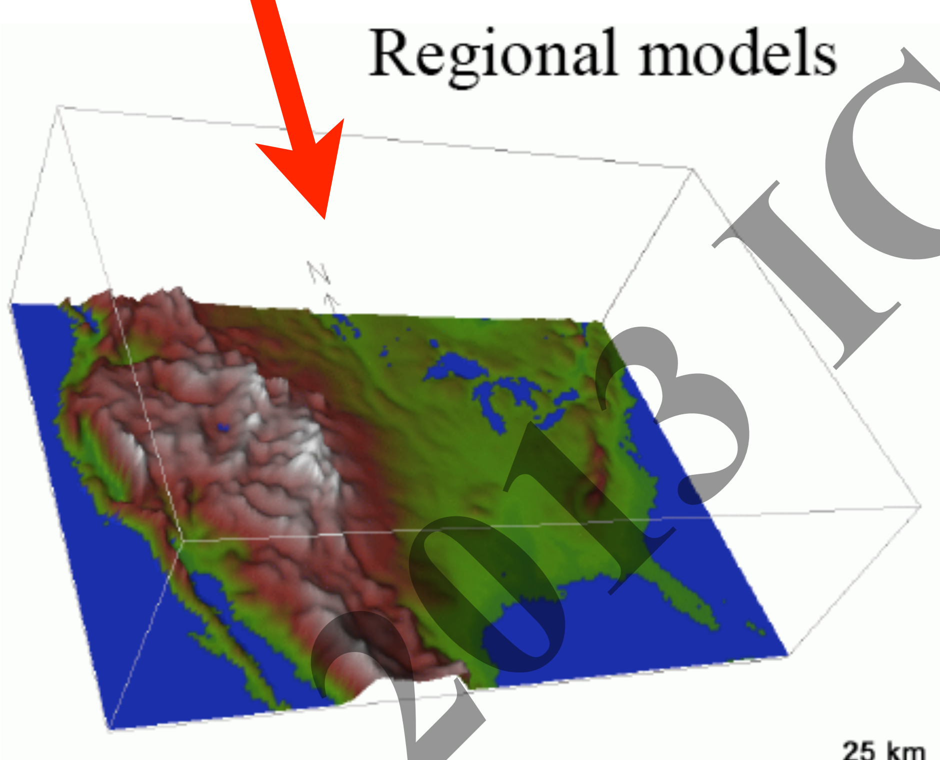


2013 ICCC

2013 ICCC

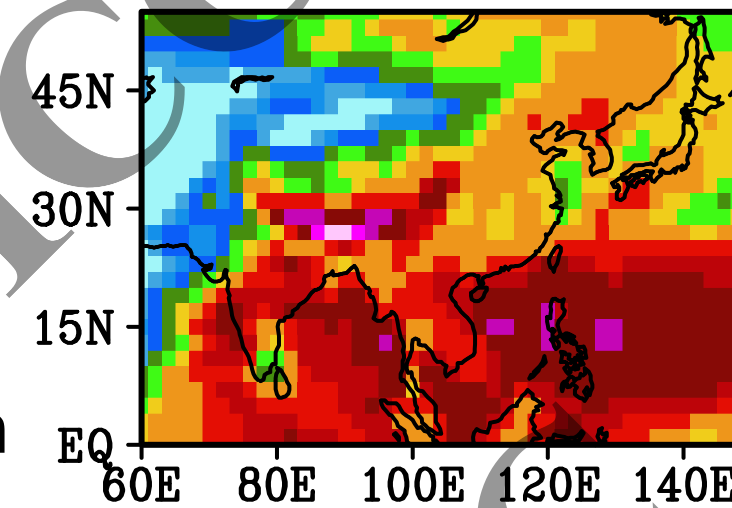
Dynamical Downscaling



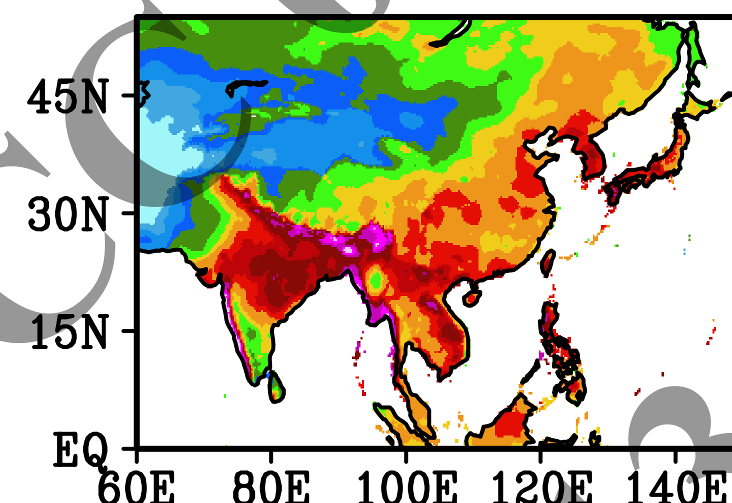


Statistical Downscaling

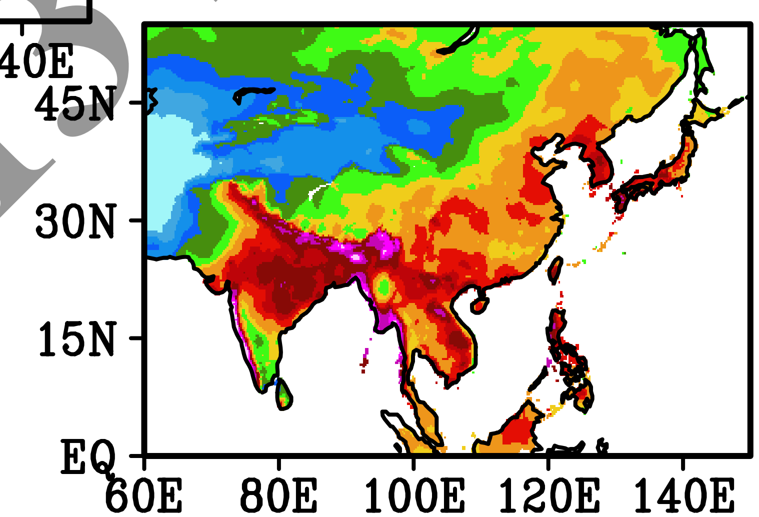
Climate Model



High Resolution Observation



Downscaled



Why statistical downscaling?

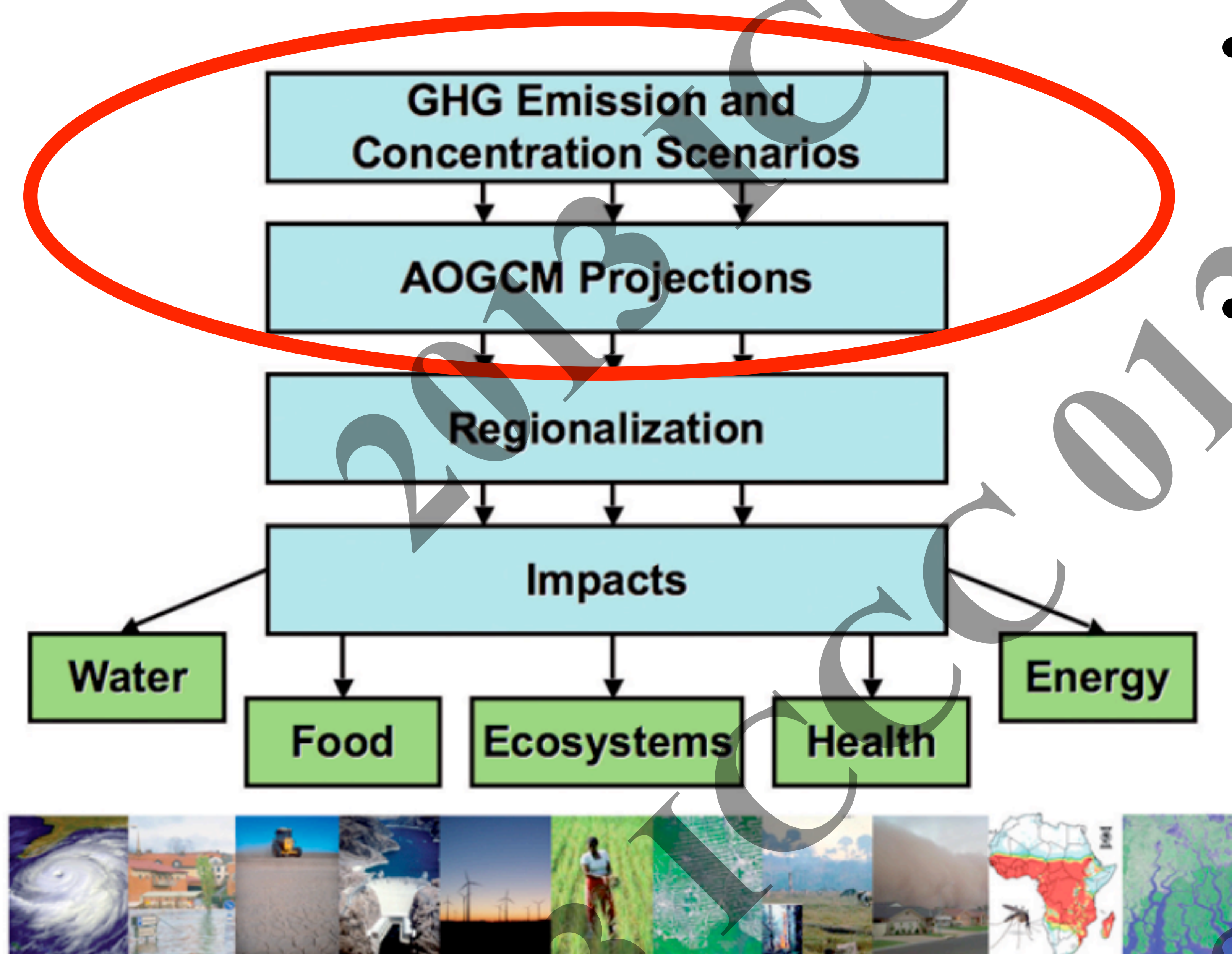


Figure 3 — Schematic depiction of the steps involved in the production of climate change information usable for impact assessment work via regionalization methods

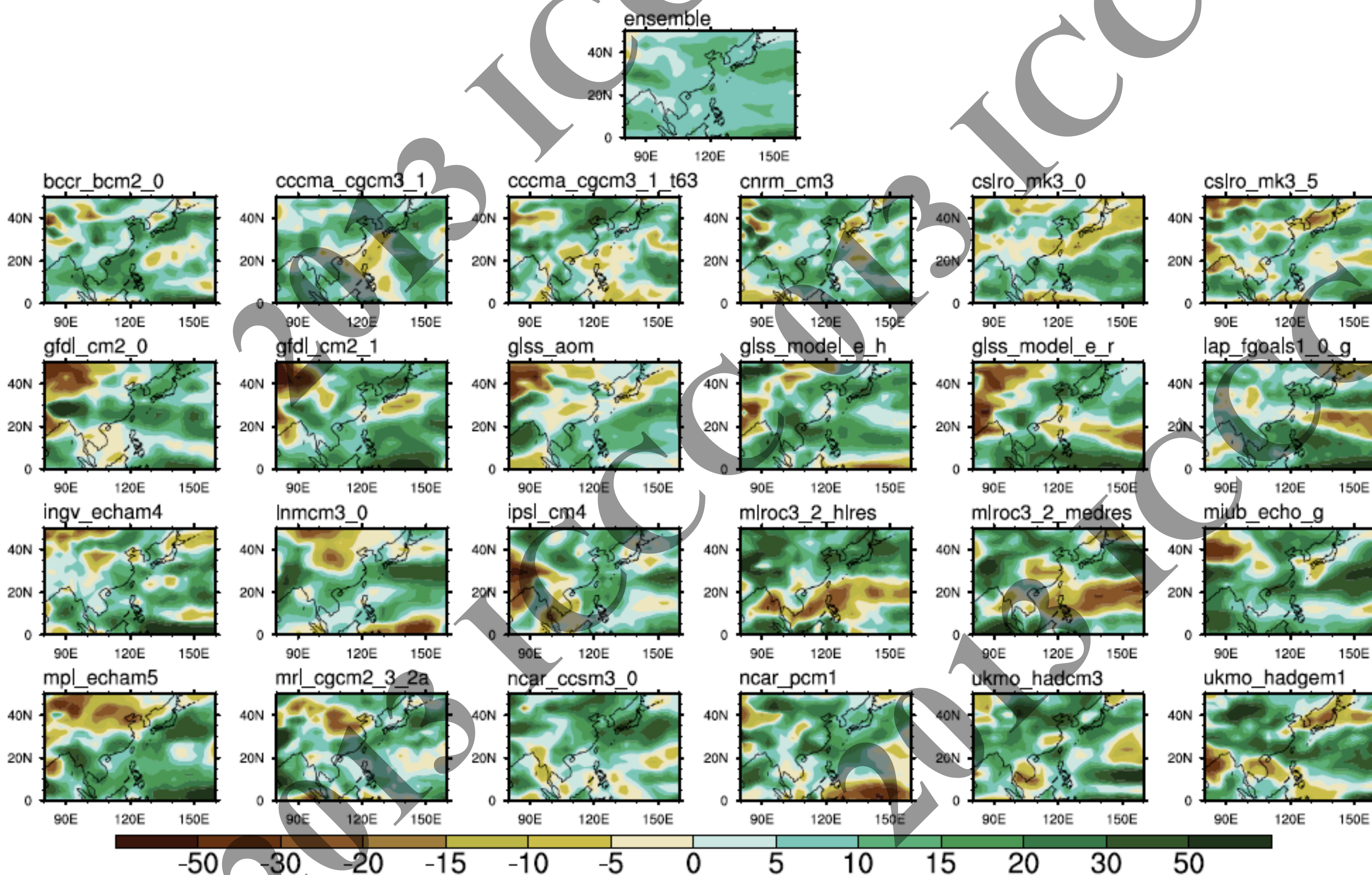
Source: Giorgi (2008)

- 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

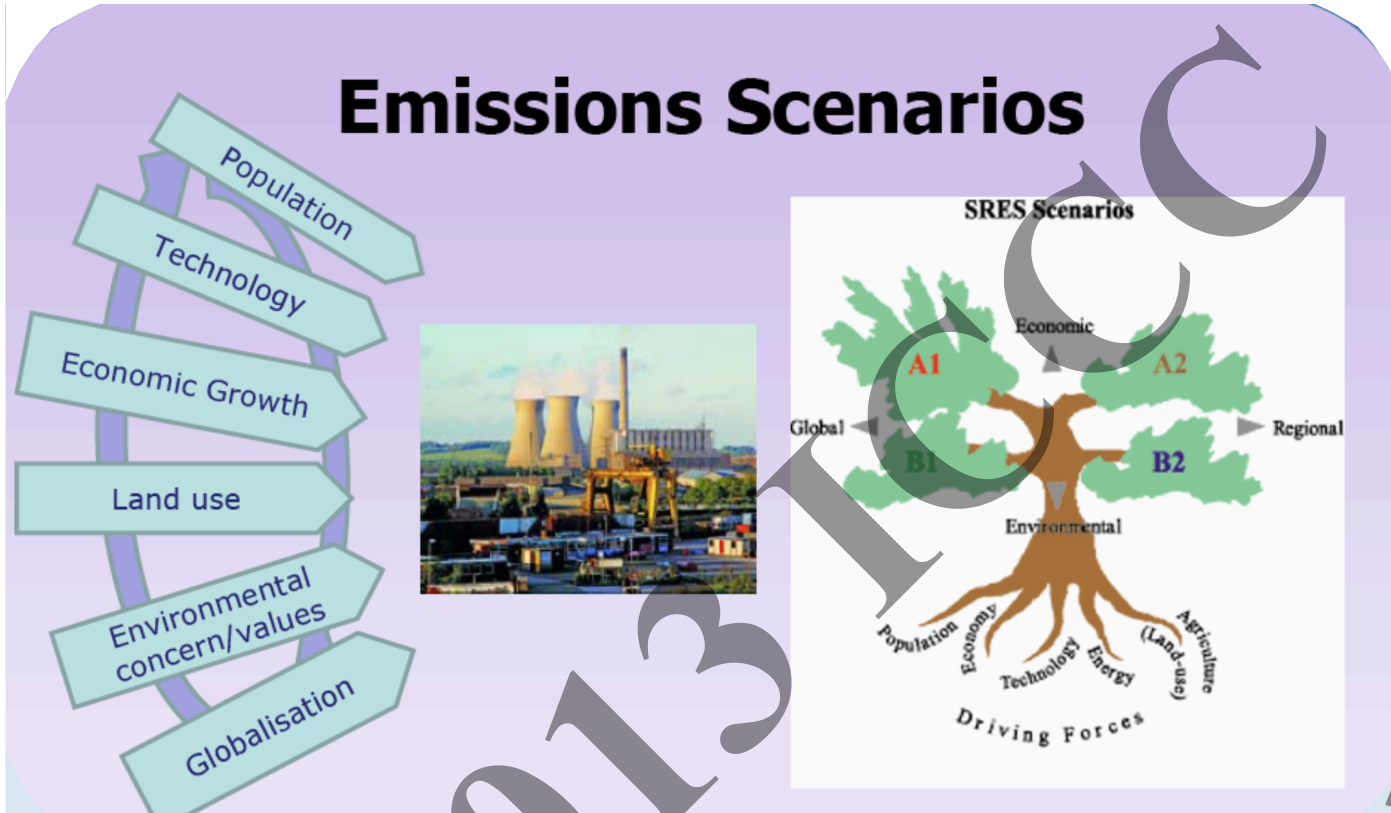
2013 ICCC 2013 ICCC 2013 ICCC

Uncertainty from Global Climate Models

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

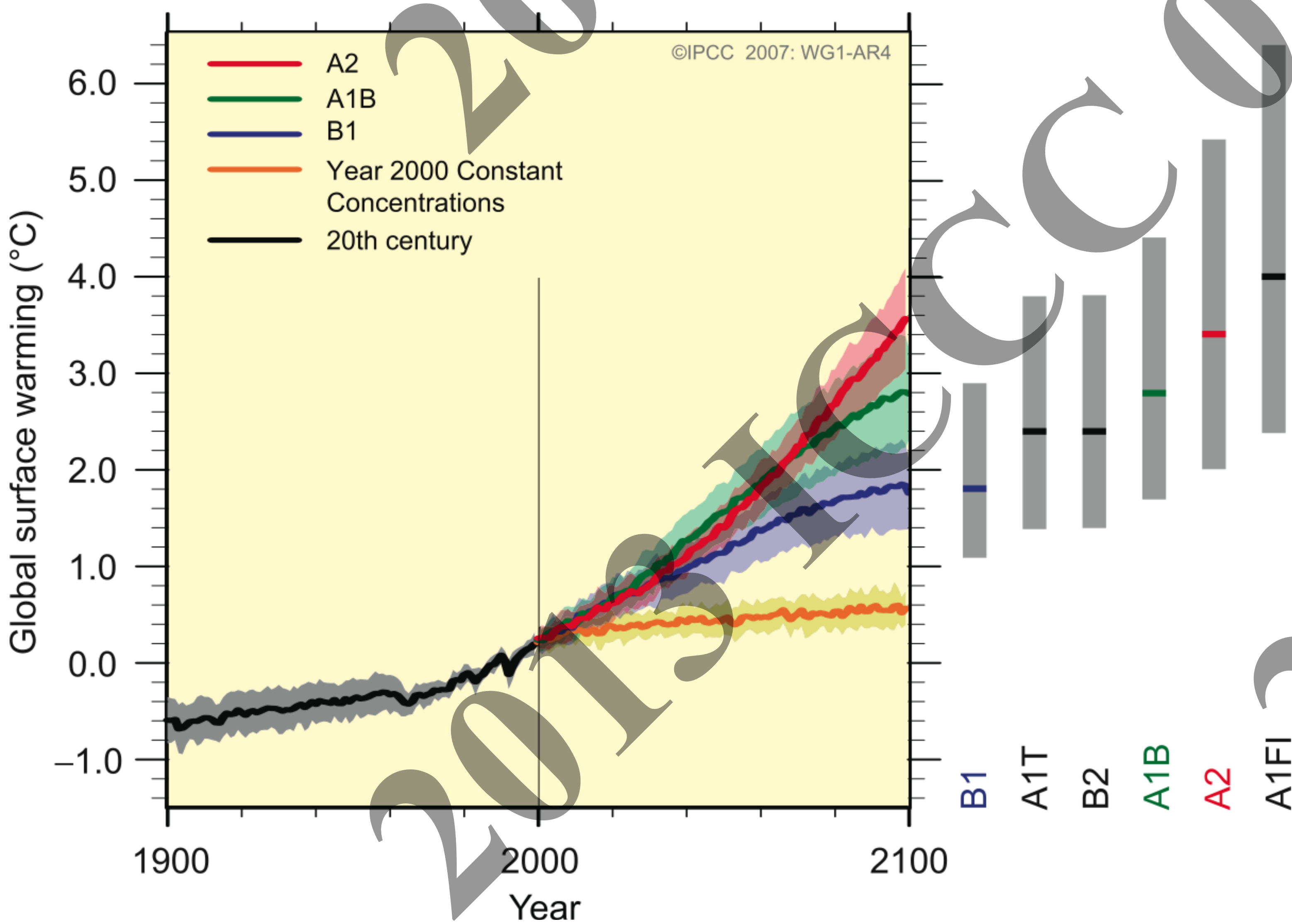


2013 ICCC



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



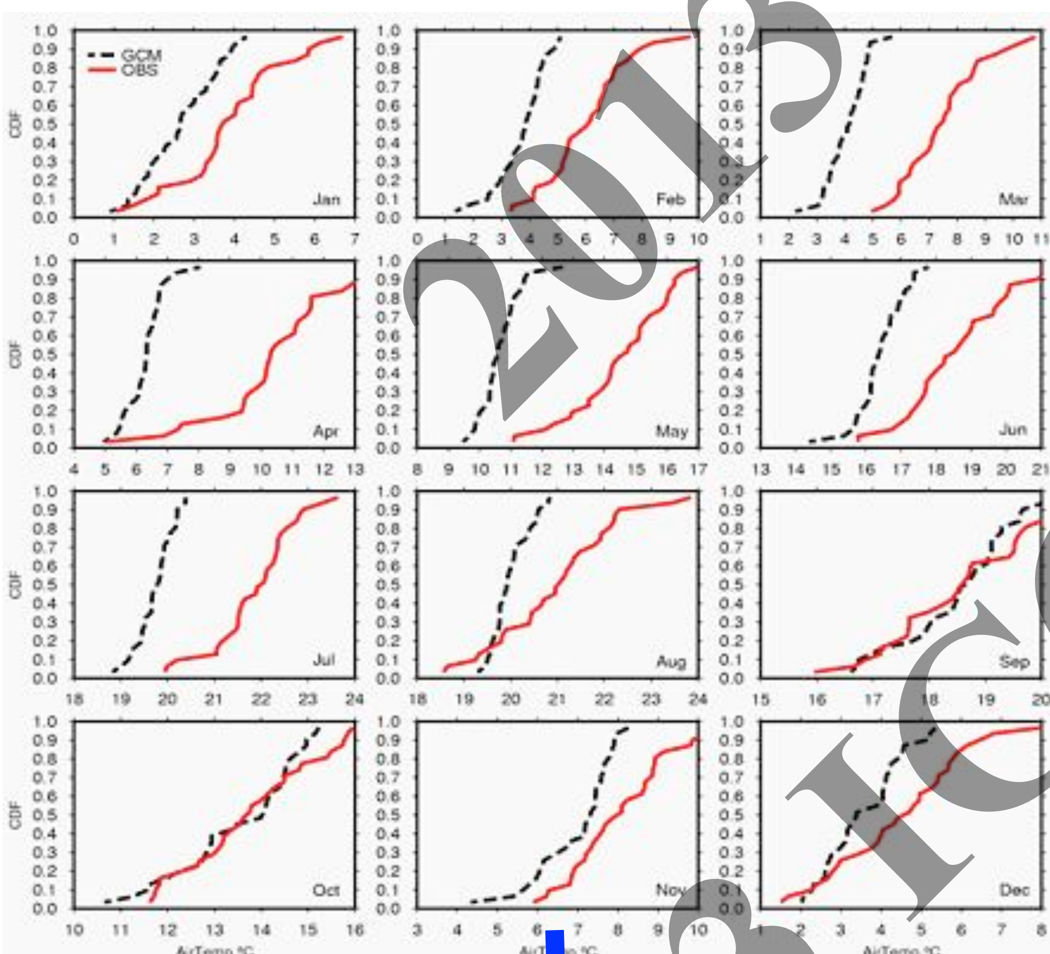
Probabilistic model future climate projection for individual scenarios

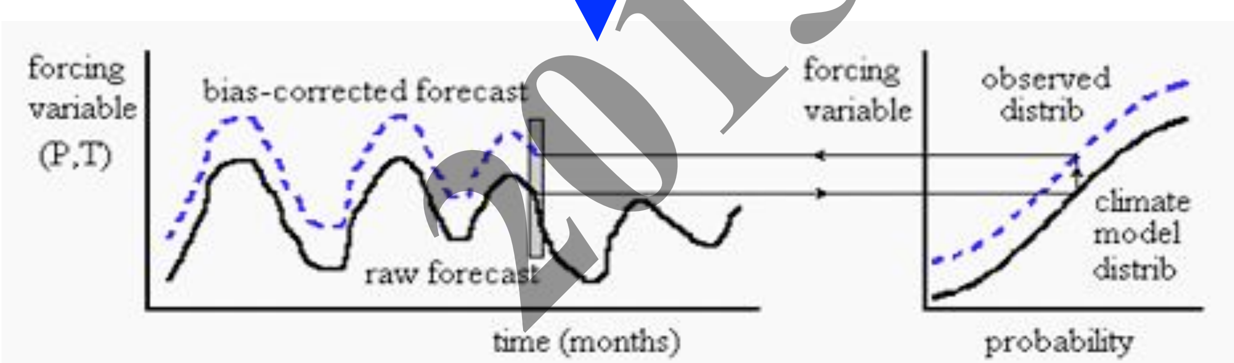
2013 ICCC
2013 ICCC
2013 ICCC
2013 ICCC

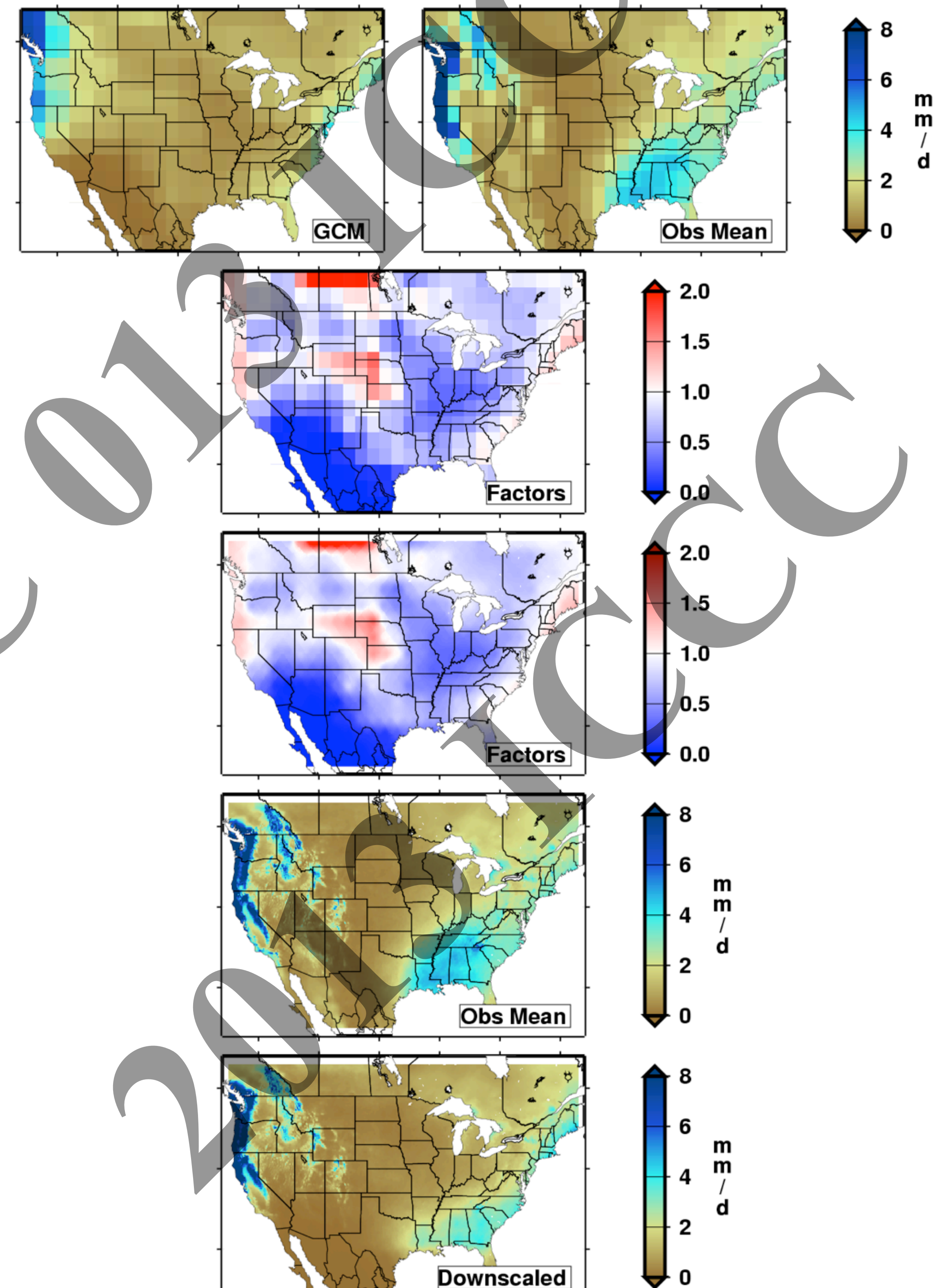
Statistical Downscaling

Wood et al. 2004, and Maurer 2007

Statistical downscaling and bias correction by cumulative distribution function and interpolation





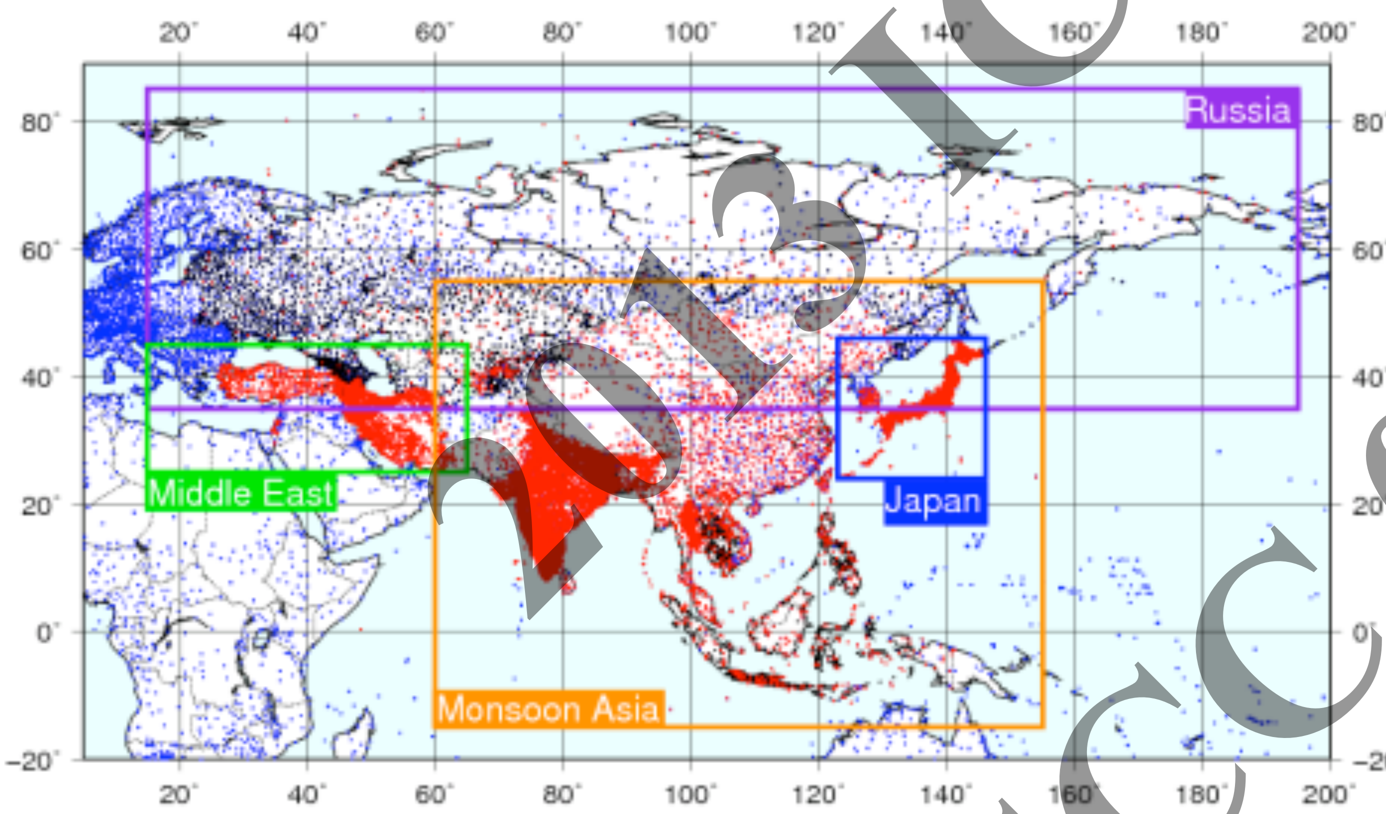


%

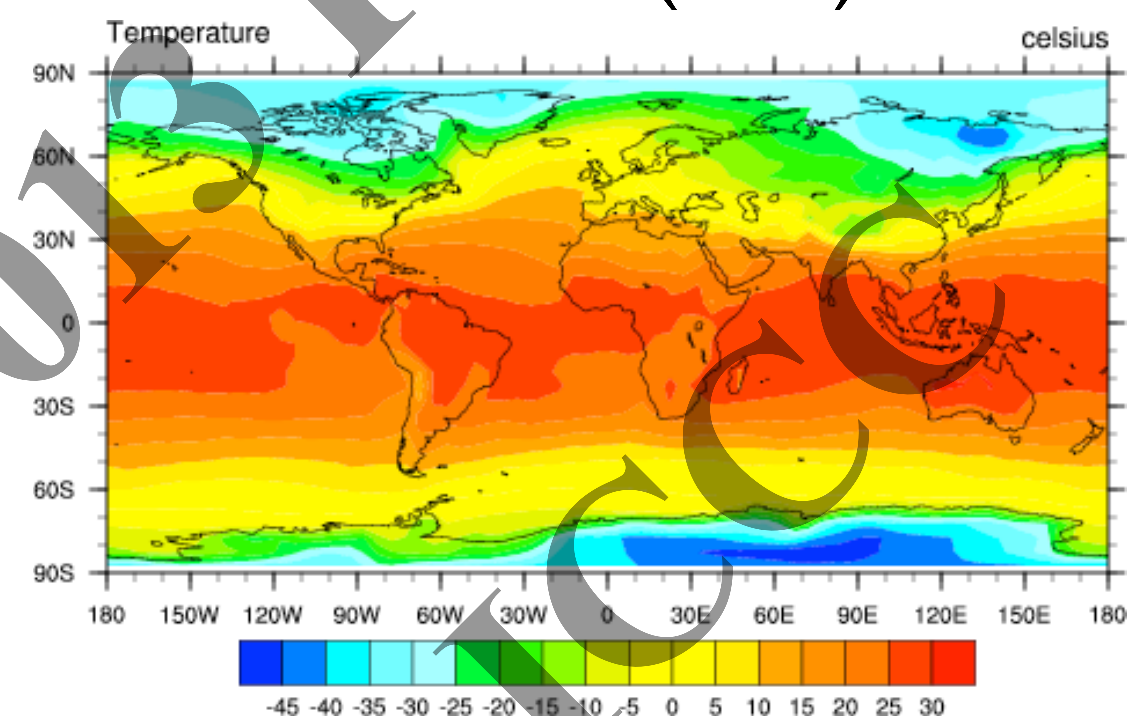
2013 ICCC

Require long-term high-resolution observations

APHRODITE (0.25°)



CRU (0.5°)



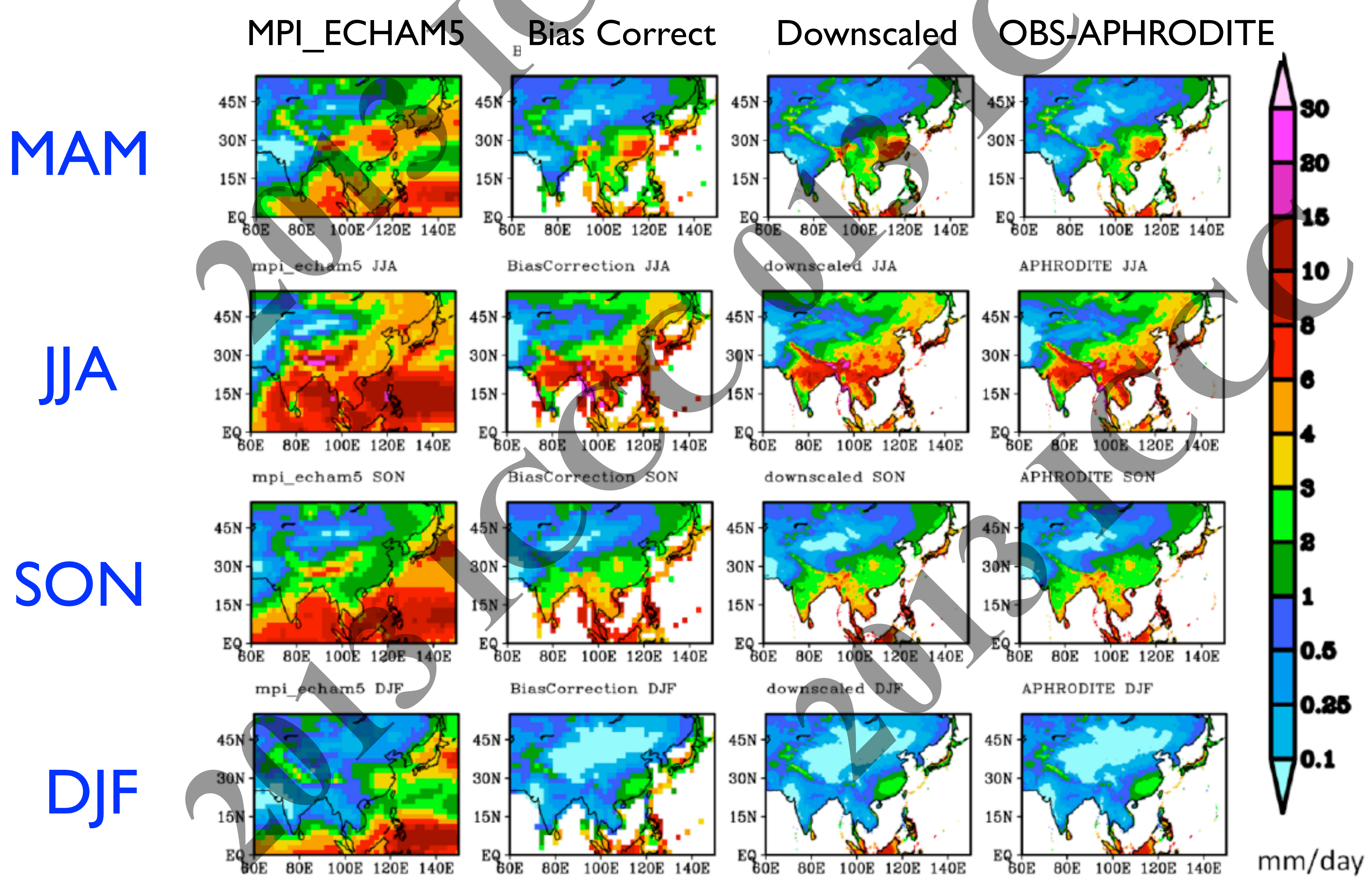
Current version: V1003R1 Download »Readme »Errata

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		

2013 ICCC 2013 ICCC 2013 ICCC

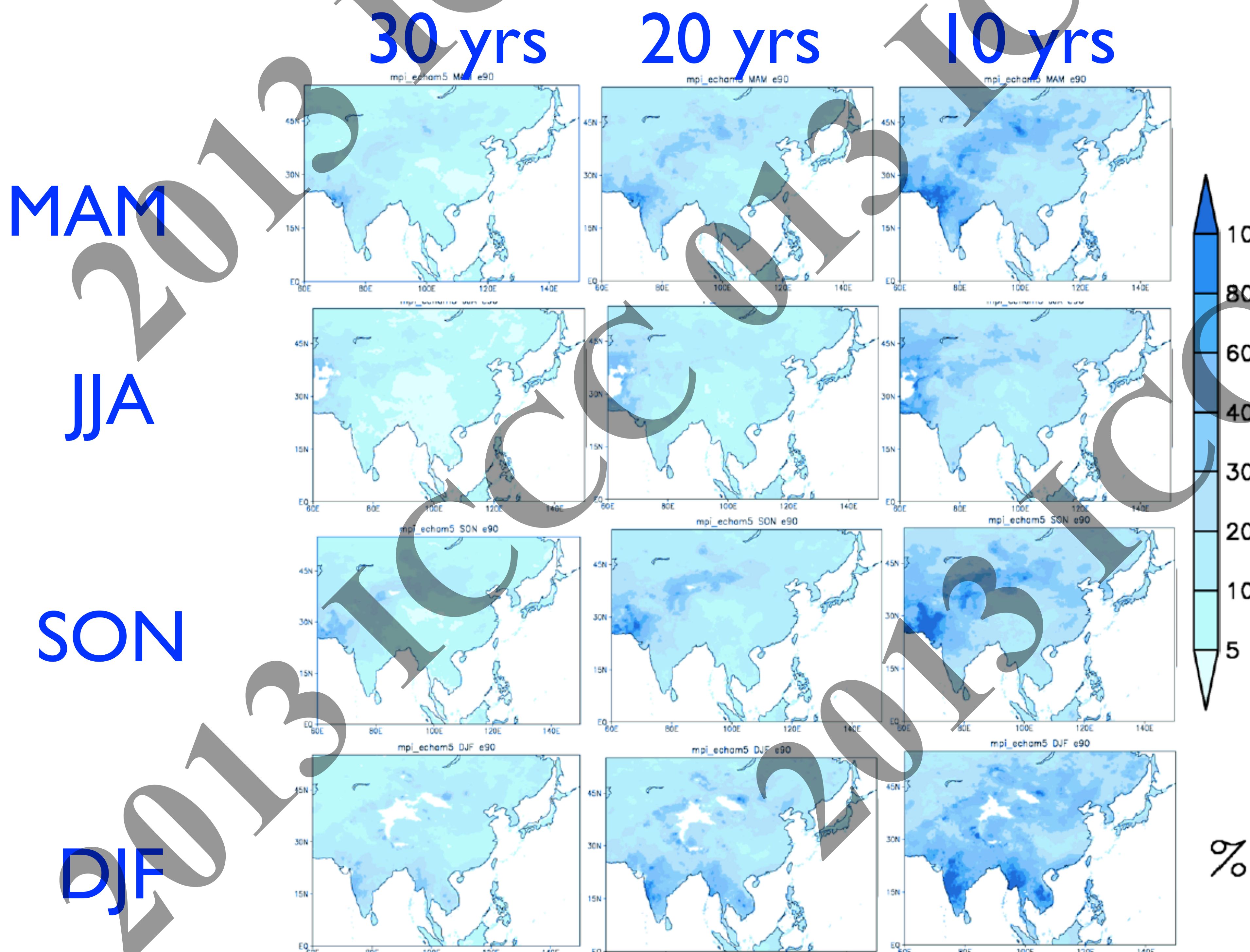
Validation

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



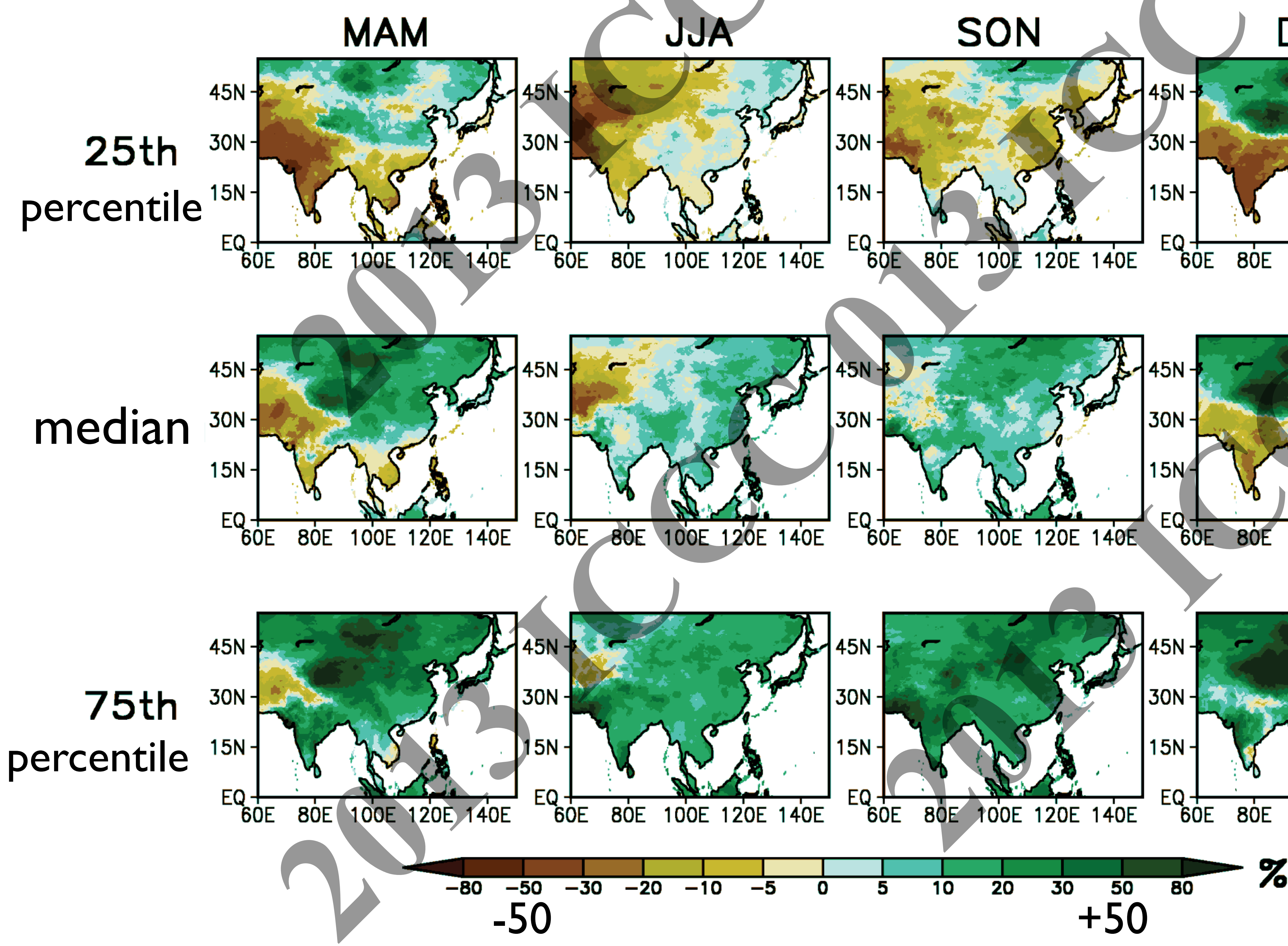
2013 ICCC

- 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)



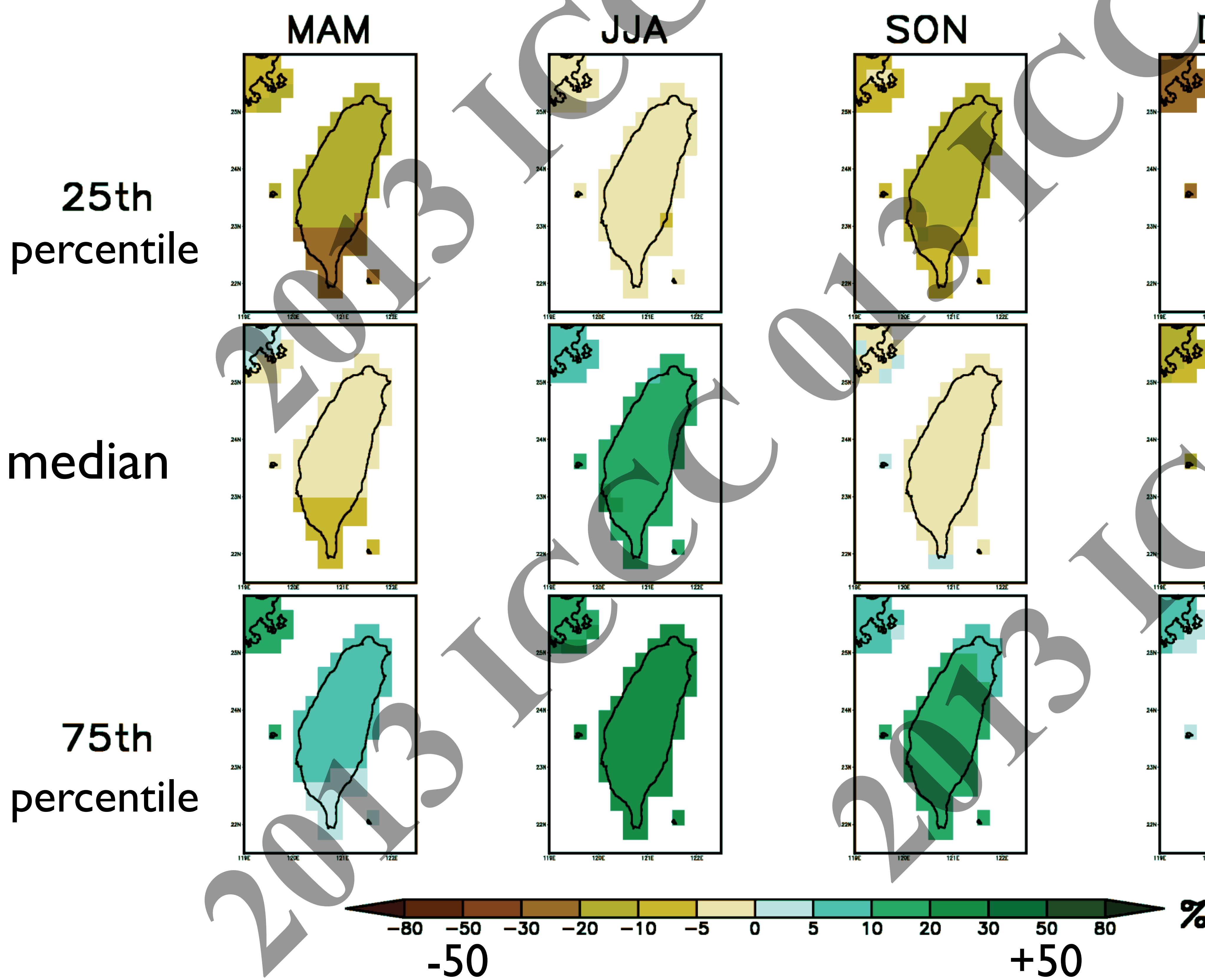
2013 ICCC

CMIP3 Model Projected Future Change in Precipitation (%) A1B

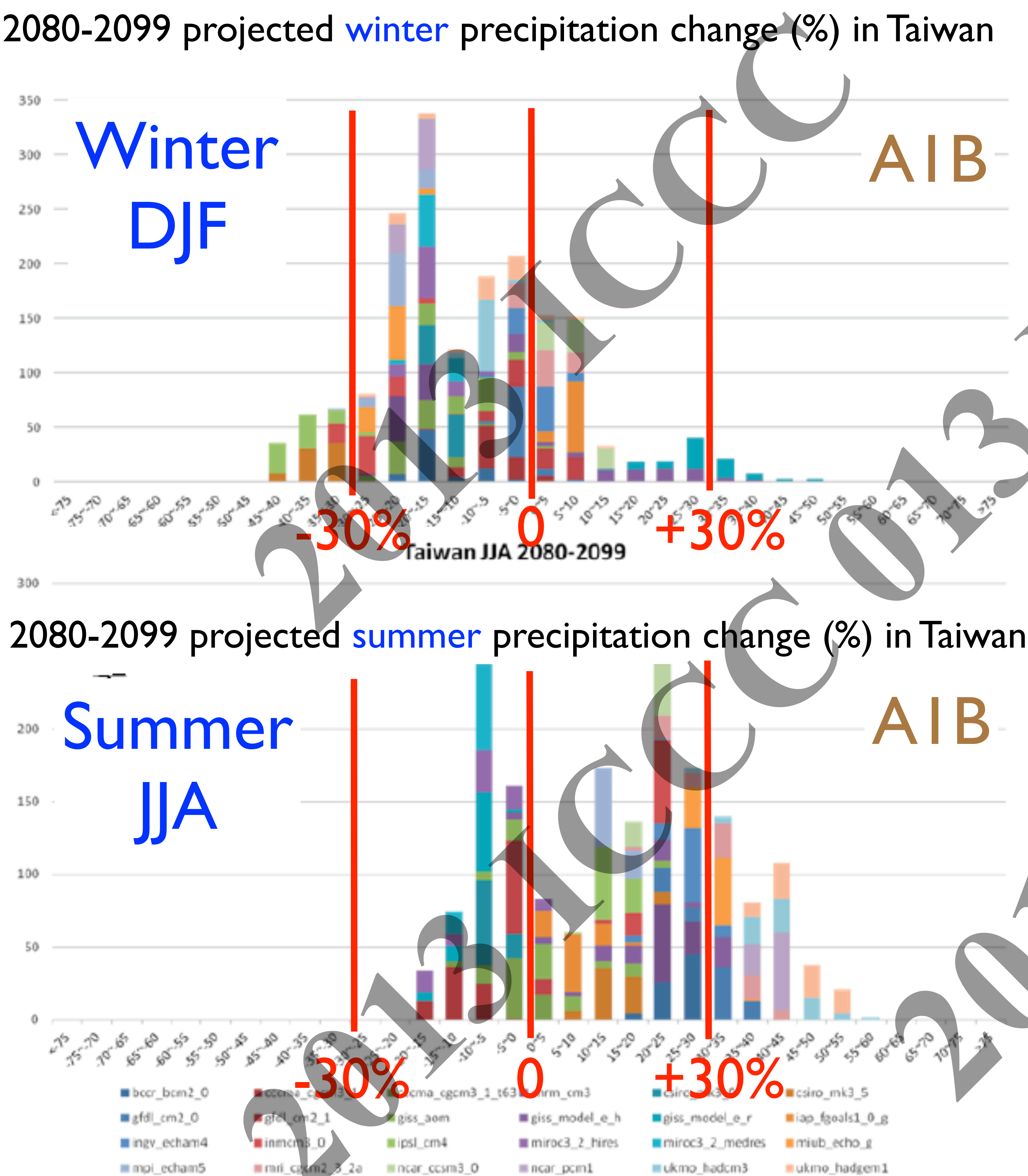


2013 ICCC

CMIP3 Model Projected Future Change in Precipitation (%) A1B



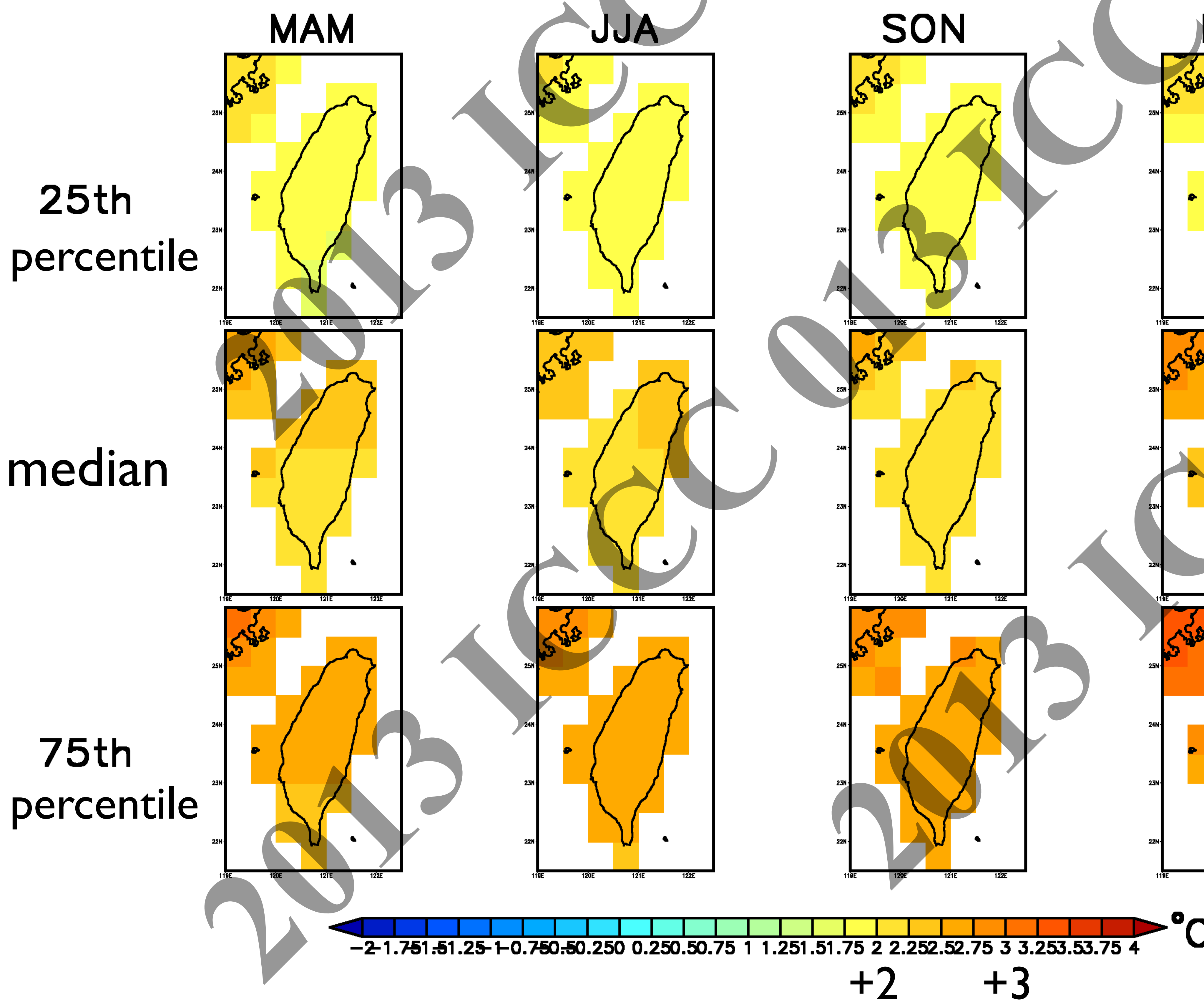
2013 ICCC



- 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)

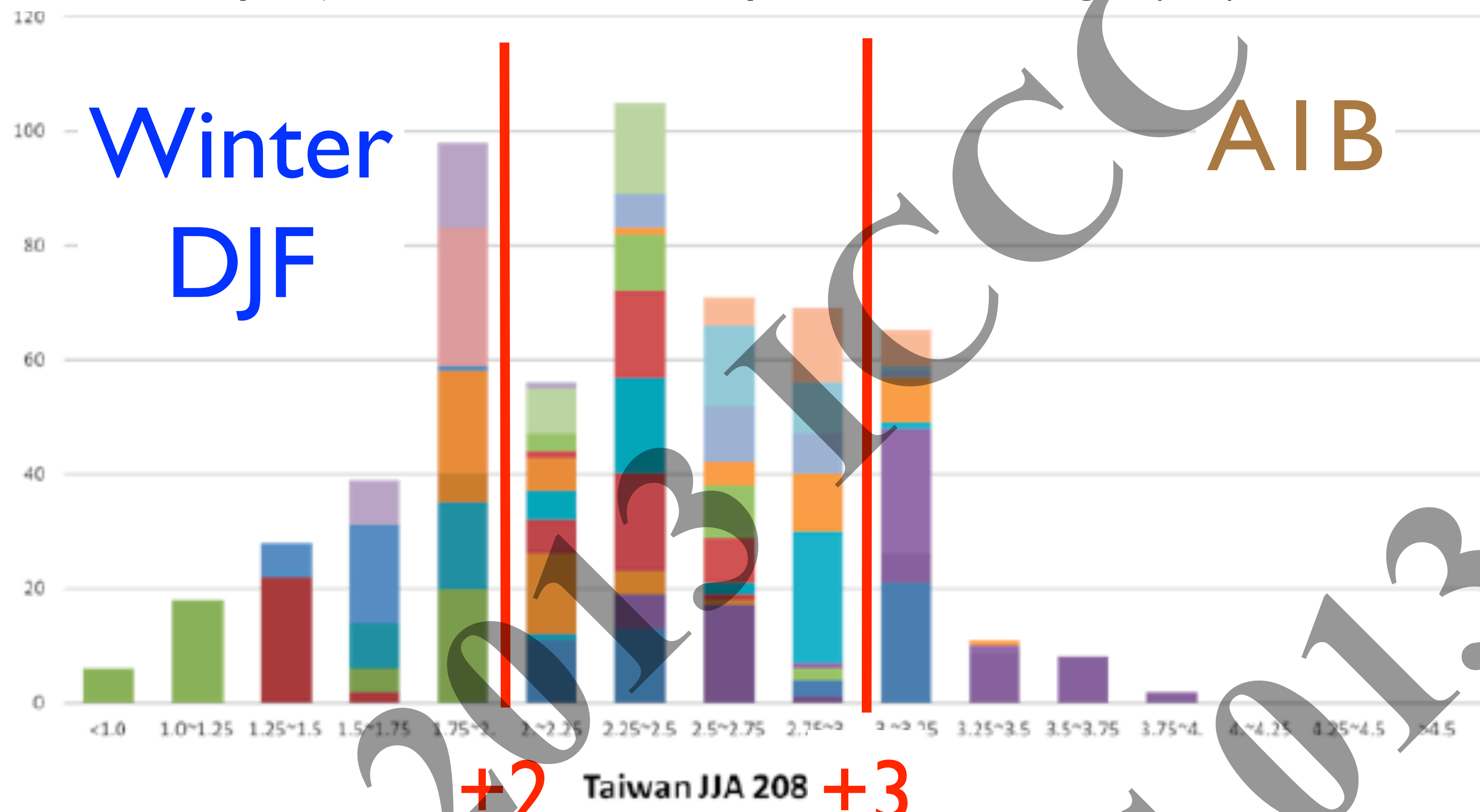
2013 ICCC
2013 ICCC
2013 ICCC
2013 ICCC

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

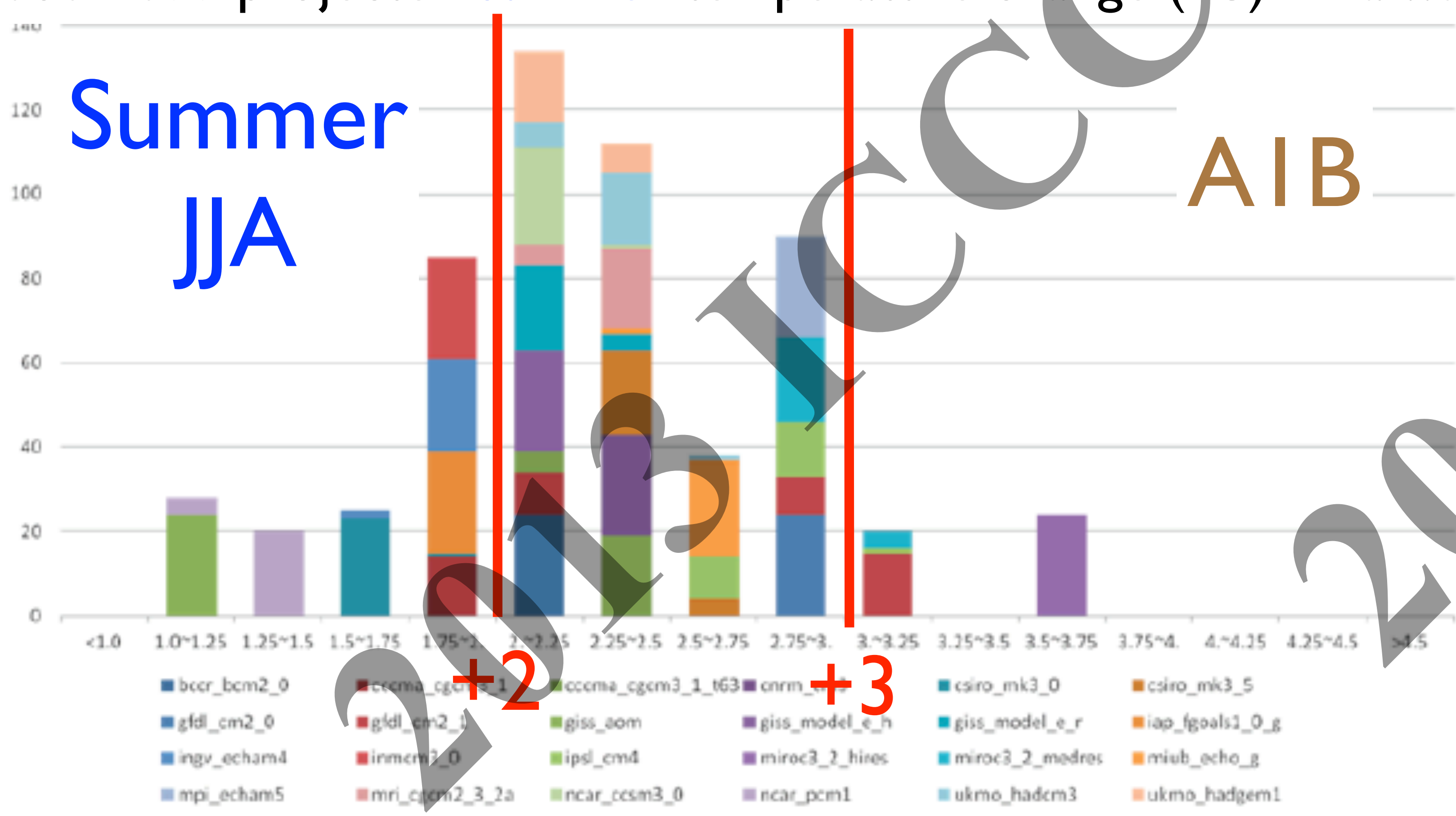


2013 ICCC

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



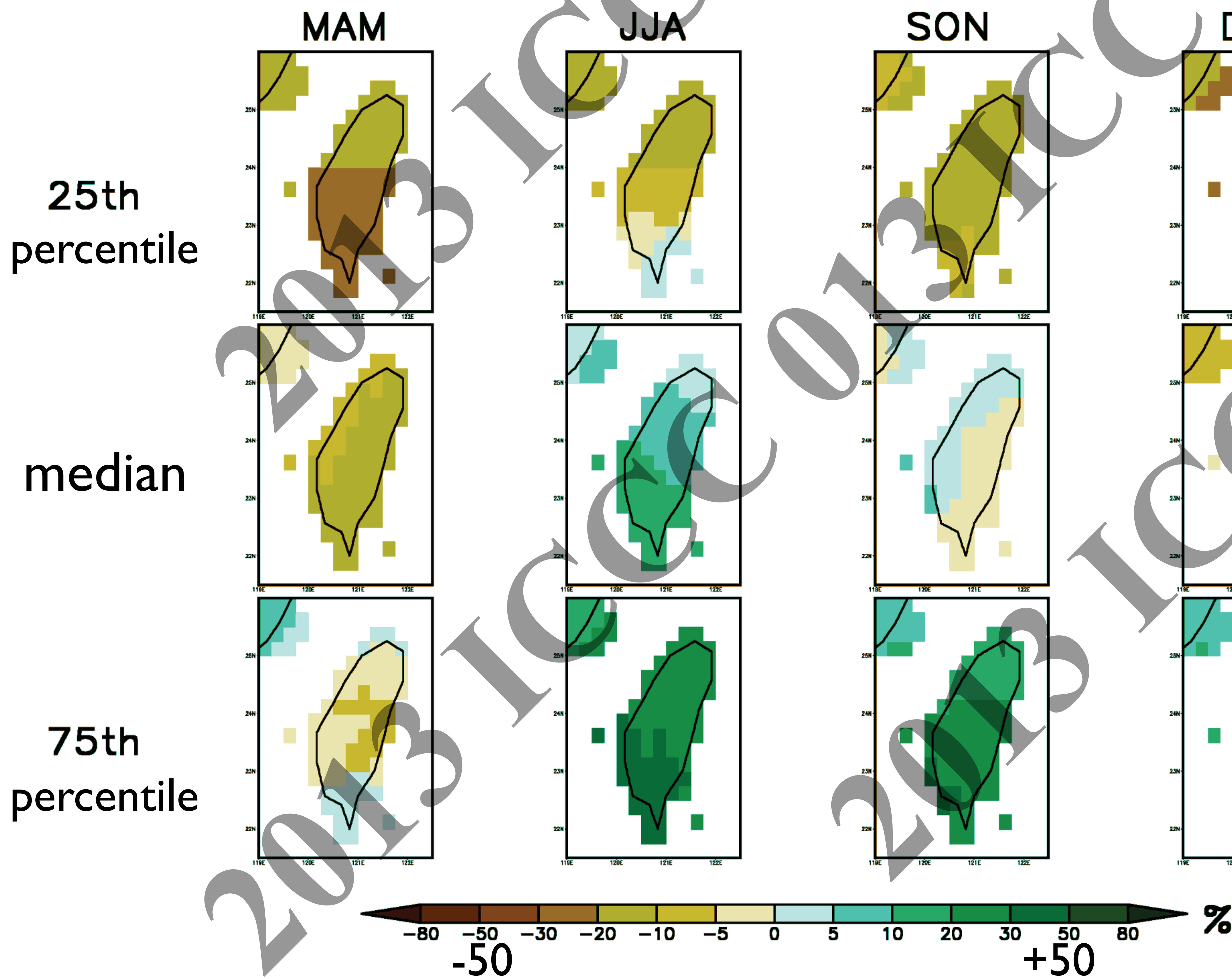
2080-2099 projected summer temperature change (°C) in Taiwan



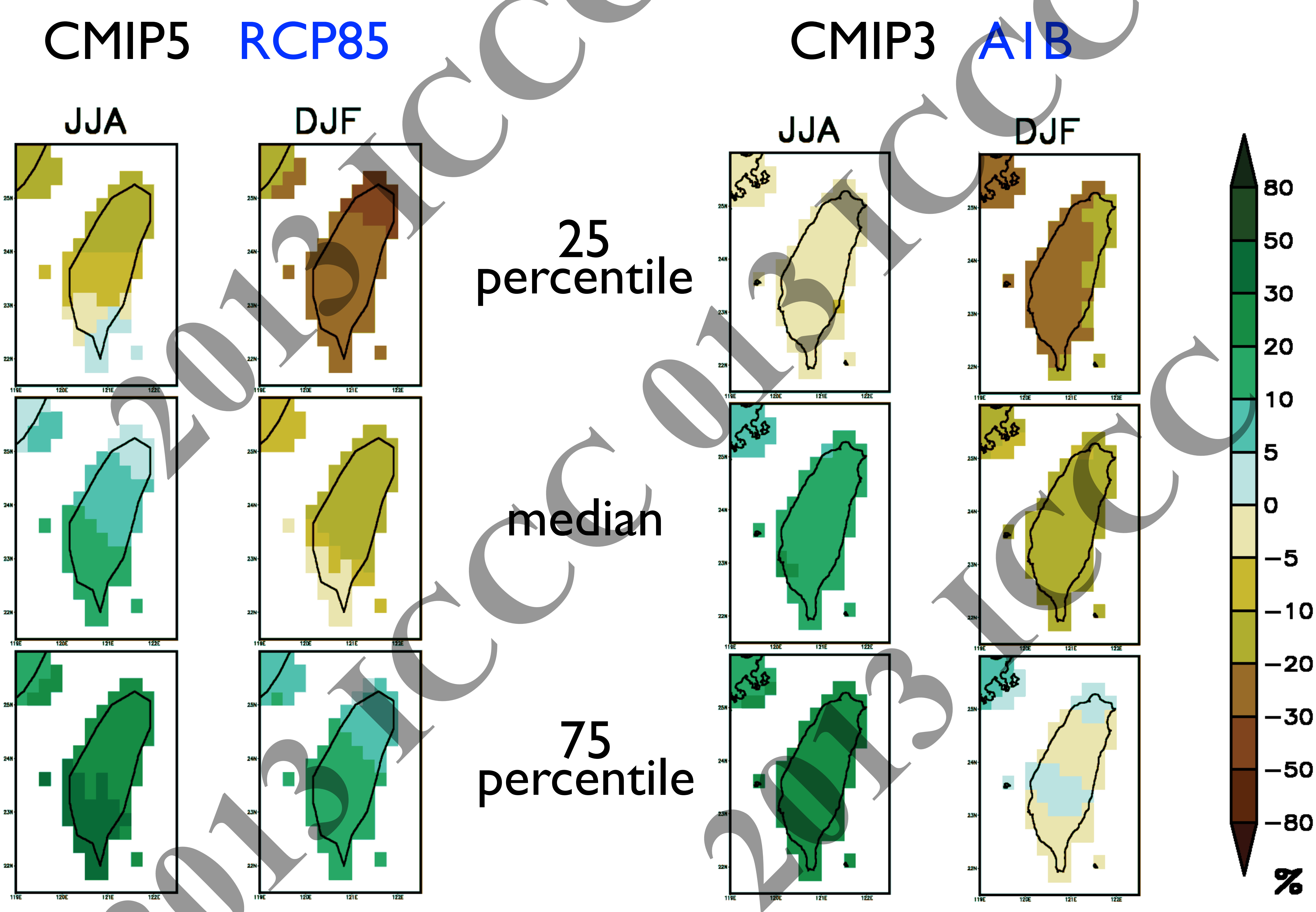
- One can also focus on area of interests and construct PDF for projected future temperature change from all models (Taiwan: 75 grids x 24 models)
- Ensemble of opportunity (probability)

2013 ICCC 2013 ICCC 2013 ICCC 2013 ICCC

CMIP5 Model Projected Future Change in Precipitation (%) RCP85

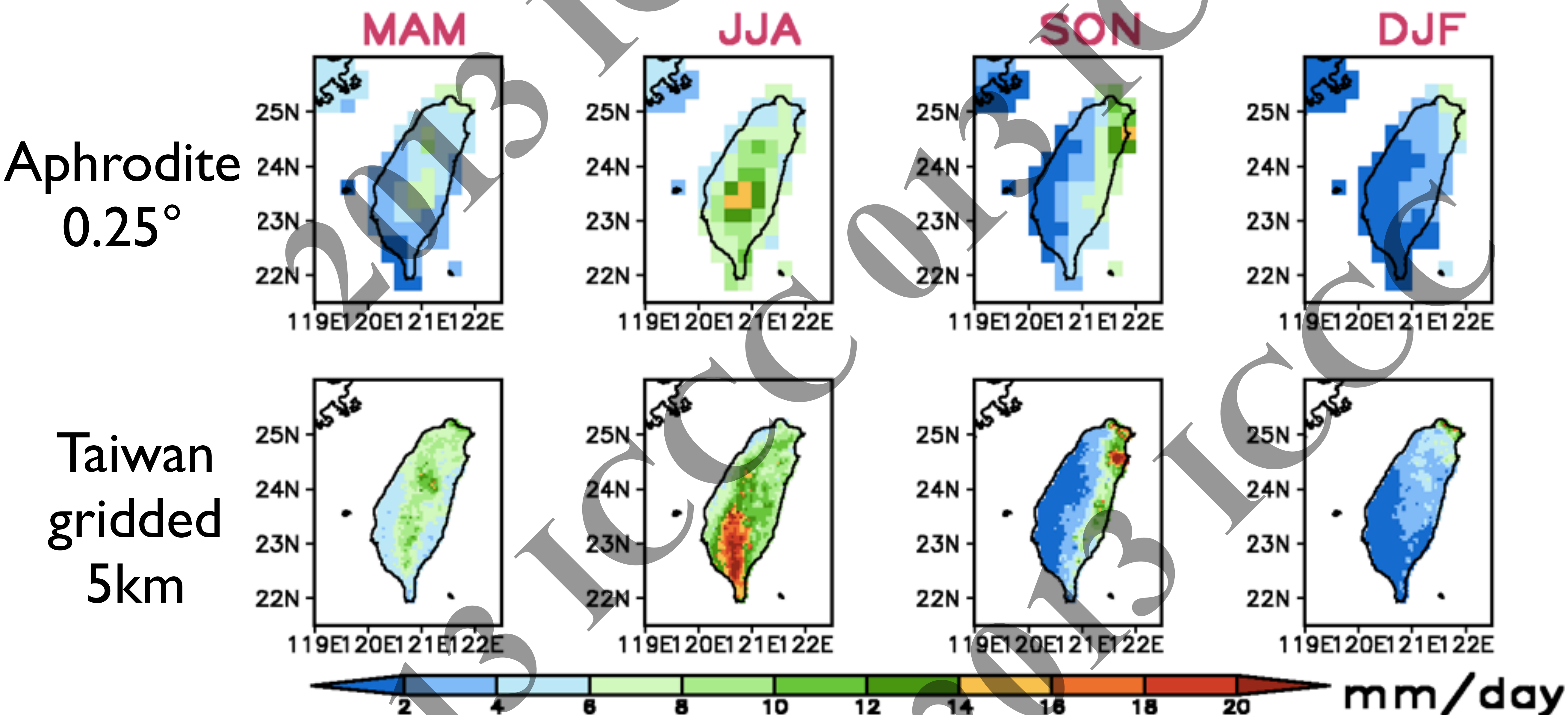


2013 ICCC


CMIP5 RCP85
CMIP3 A1B
JJA
DJF
JJA
DJF
25
percentile
median
75
percentile
80
50
30
20
10
5
0
−5
−10
−20
−30
−50
−80
%

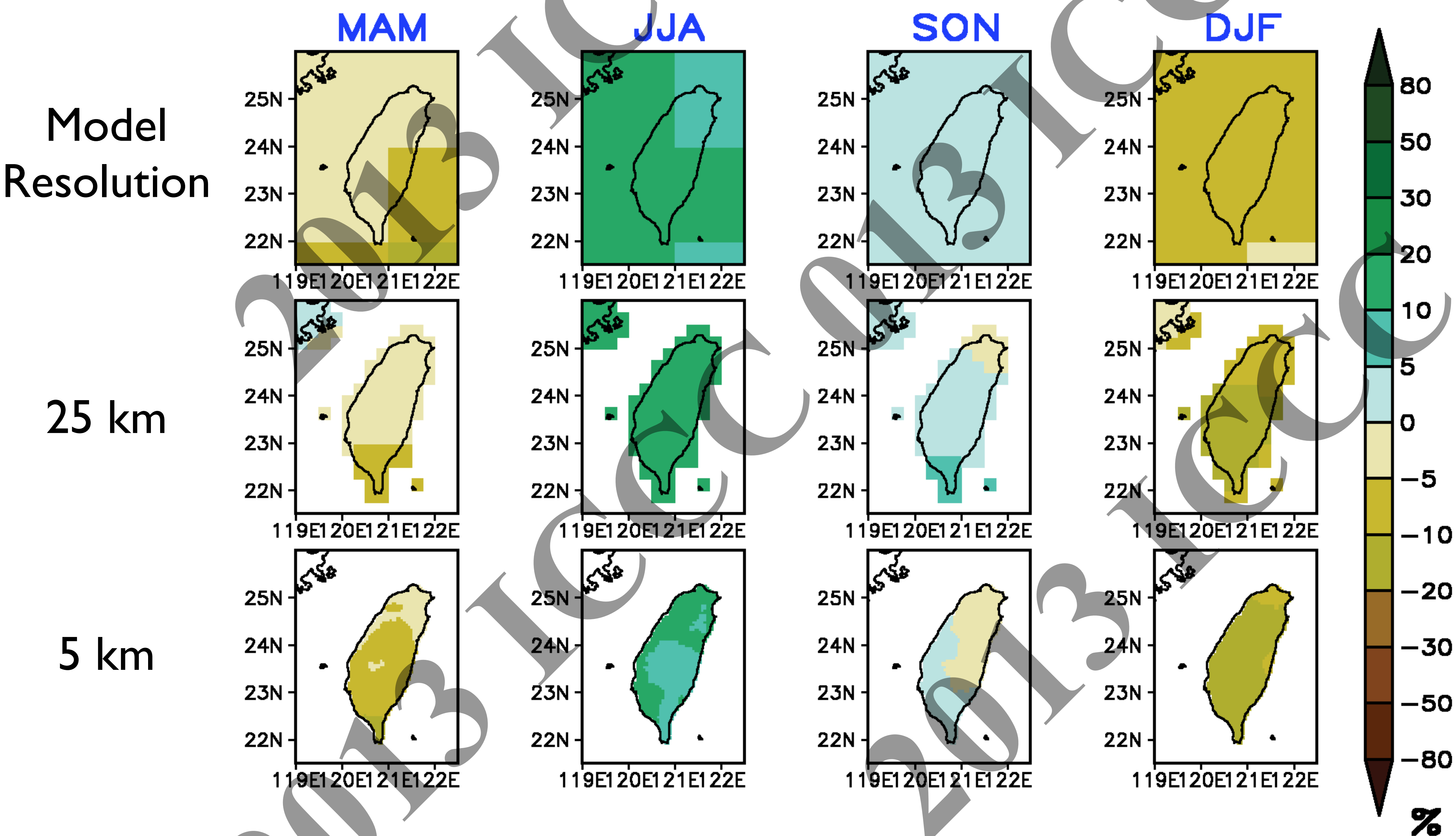
2013 ICCC

Taiwan 5km gridded rainfall better resolved local rainfall characteristics



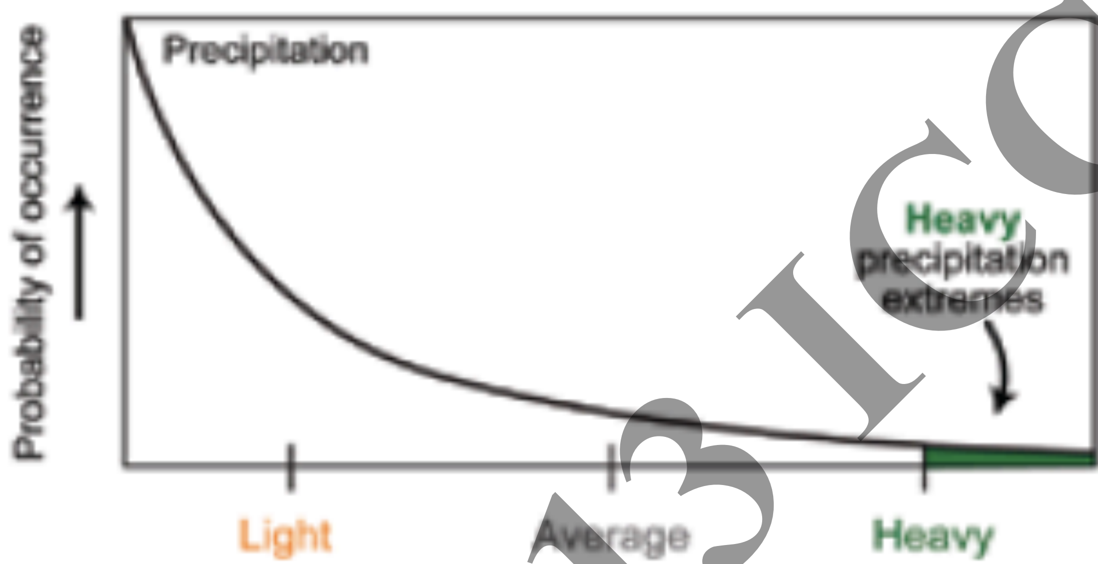
2013 ICCC

CMIP3 Model Projected Future Change in Precipitation (%) A1B

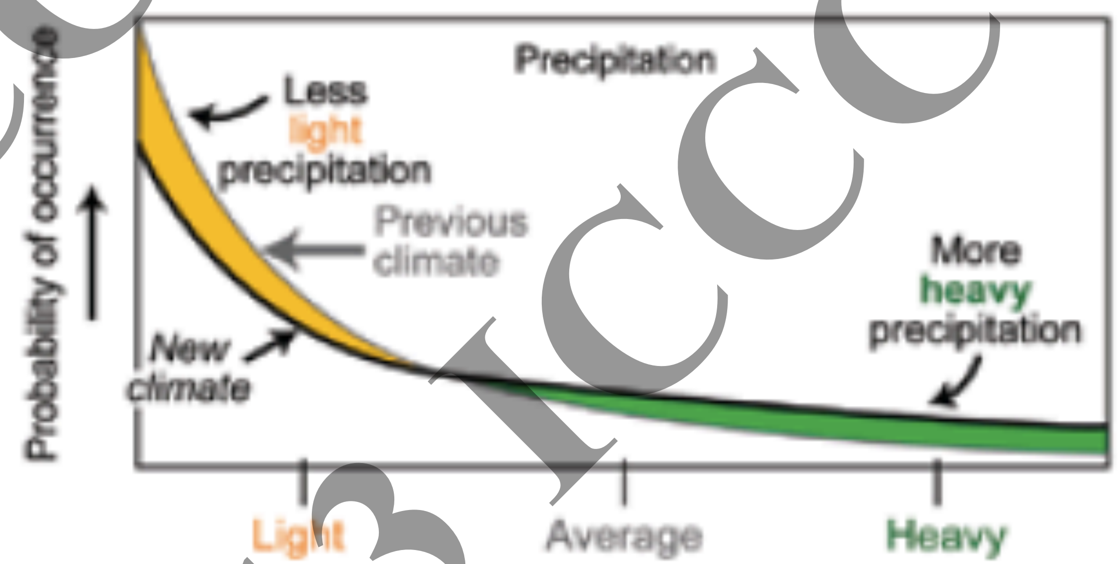


2013 ICCC

What is extreme?

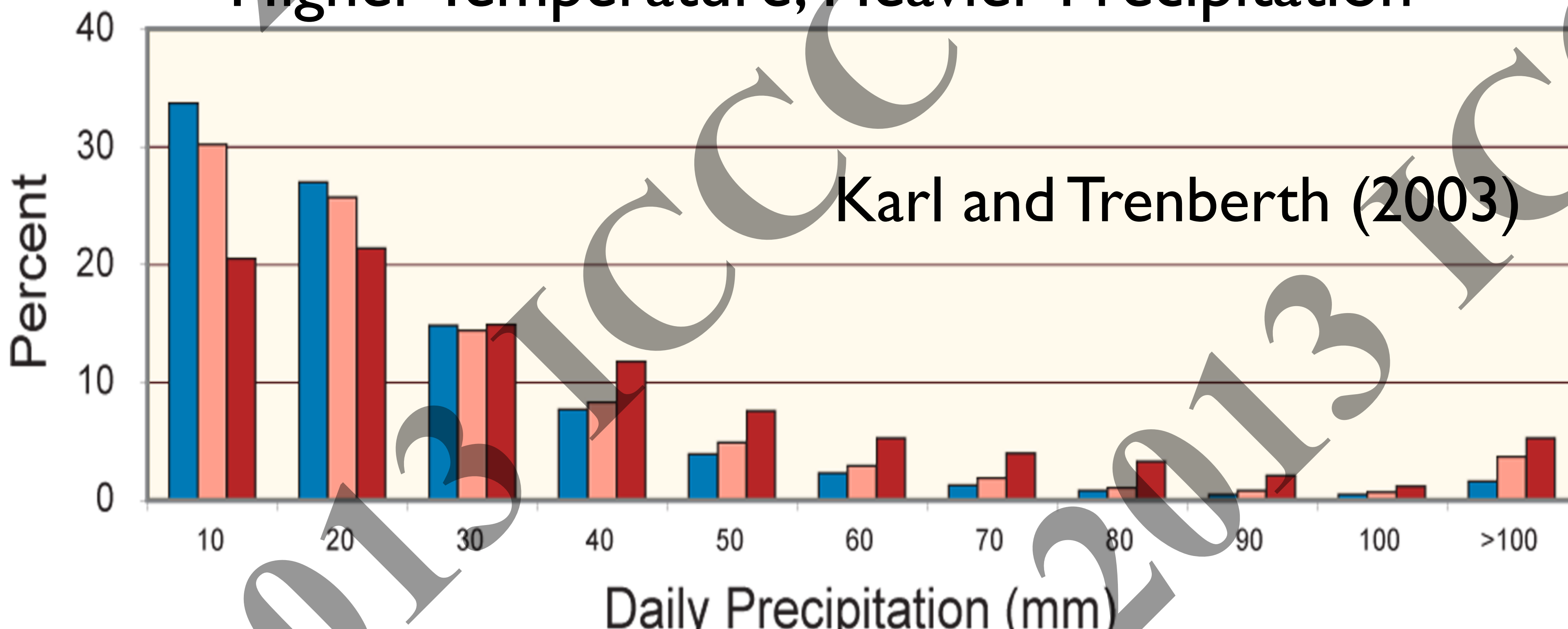


Change in probability of extremes



US Climate Change Science Program (2008)

Higher Temperature, Heavier Precipitation

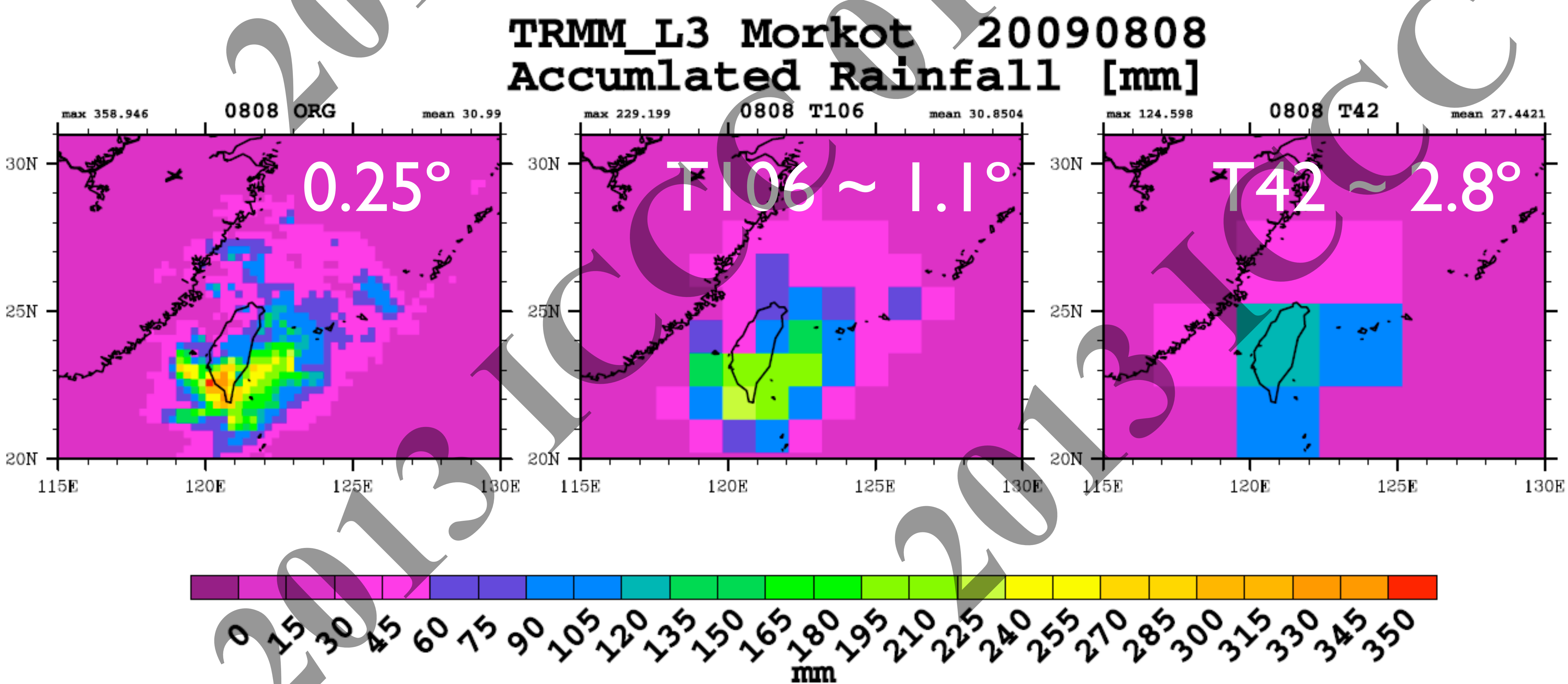


Percent of total seasonal precipitation for stations with 230mm±5mm falling into 10mm daily intervals based on seasonal mean temperature. Blue bar -3˚C to 19˚C, pink bar 19˚C to 29˚C, dark red bar 29˚C to 35˚C, based on 51, 37 and 12 stations

2013 ICCC

Statistical downscaling for the extremes?

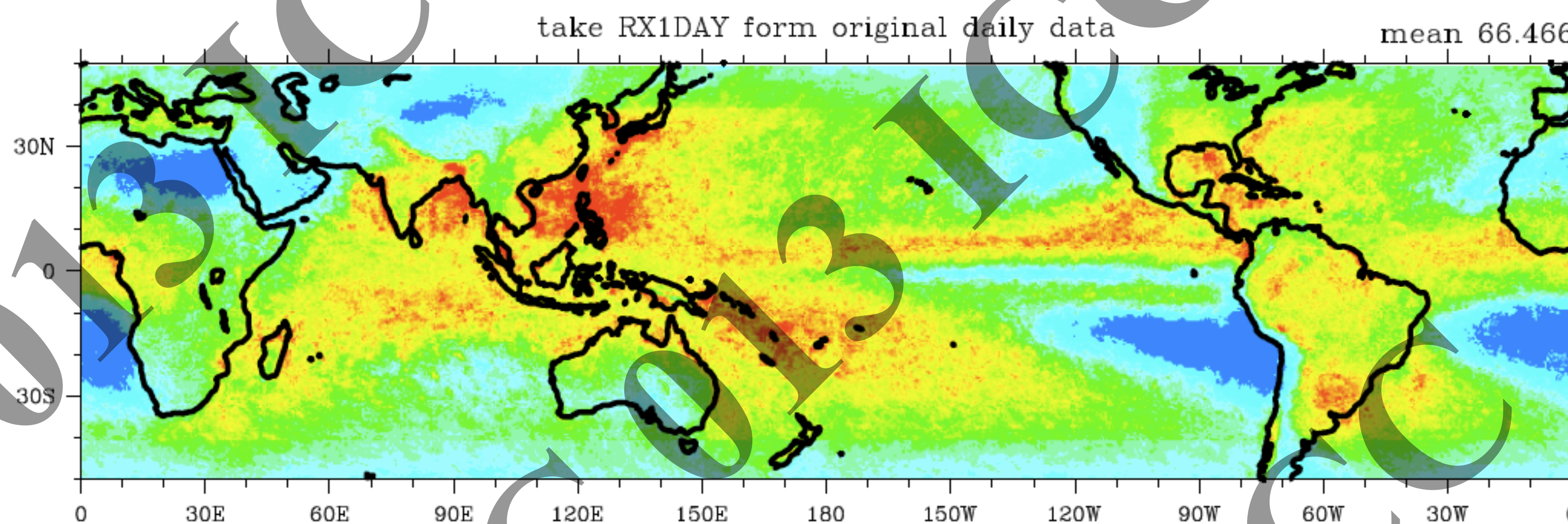
High resolution observed daily rainfall analysis
regrid to typical model resolution



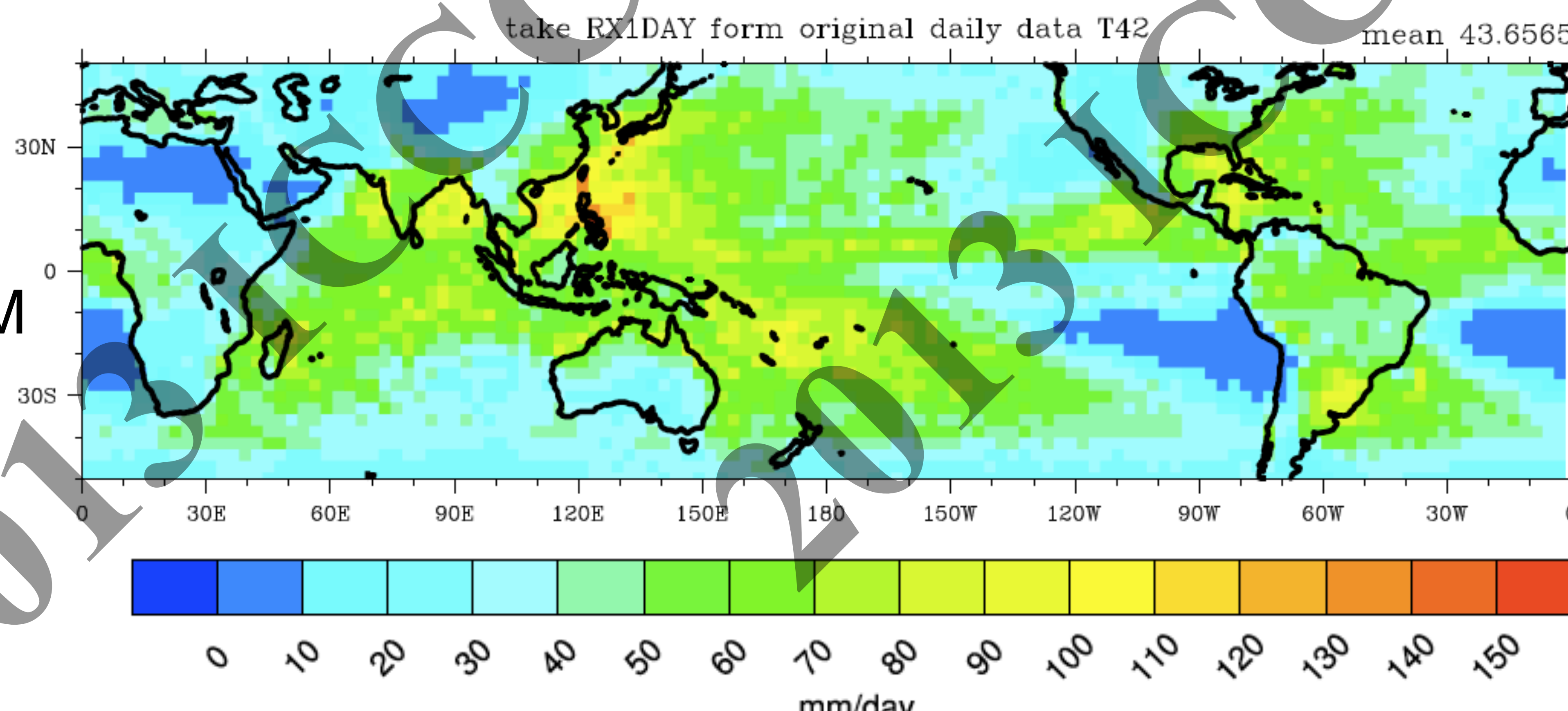
2013 ICCC

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)



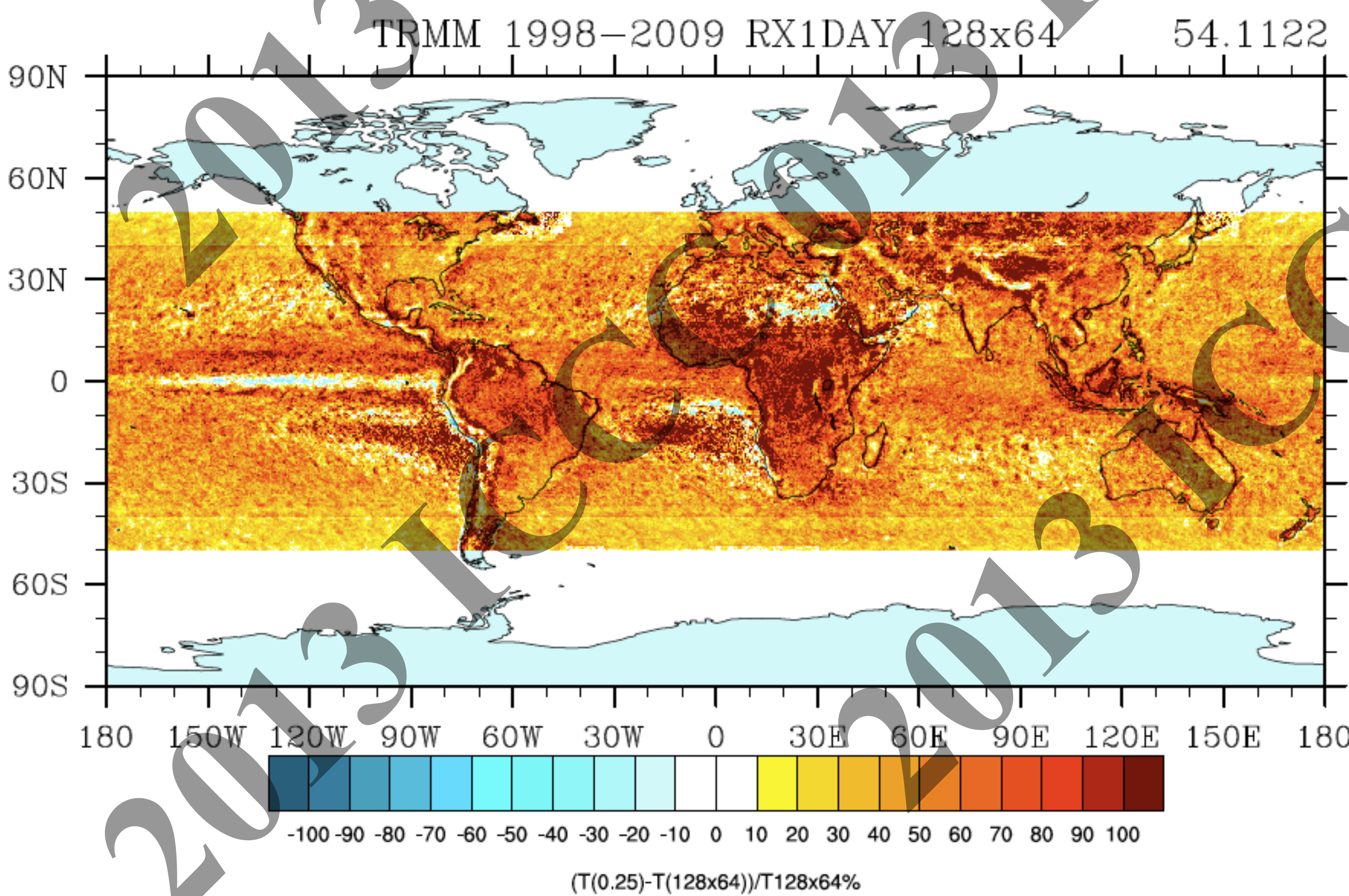
Annual maximum daily rainfall (Rx1day) at T42 derived from TRMM



2013 ICCC
2013 ICCC
2013 ICCC
2013 ICCC

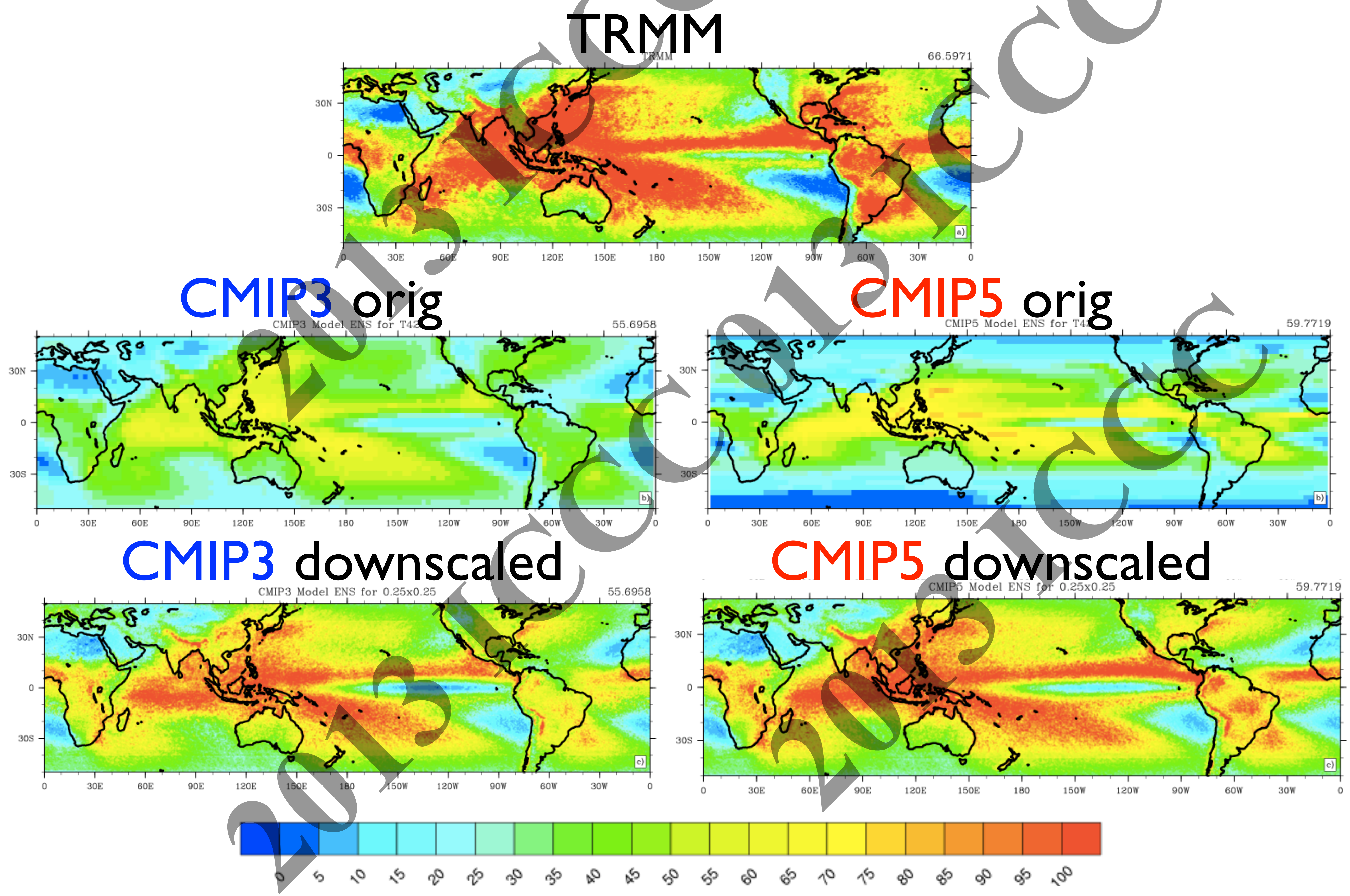
Correct the Spatial Scale Dependence of high-impact weather extremes using observational estimates

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

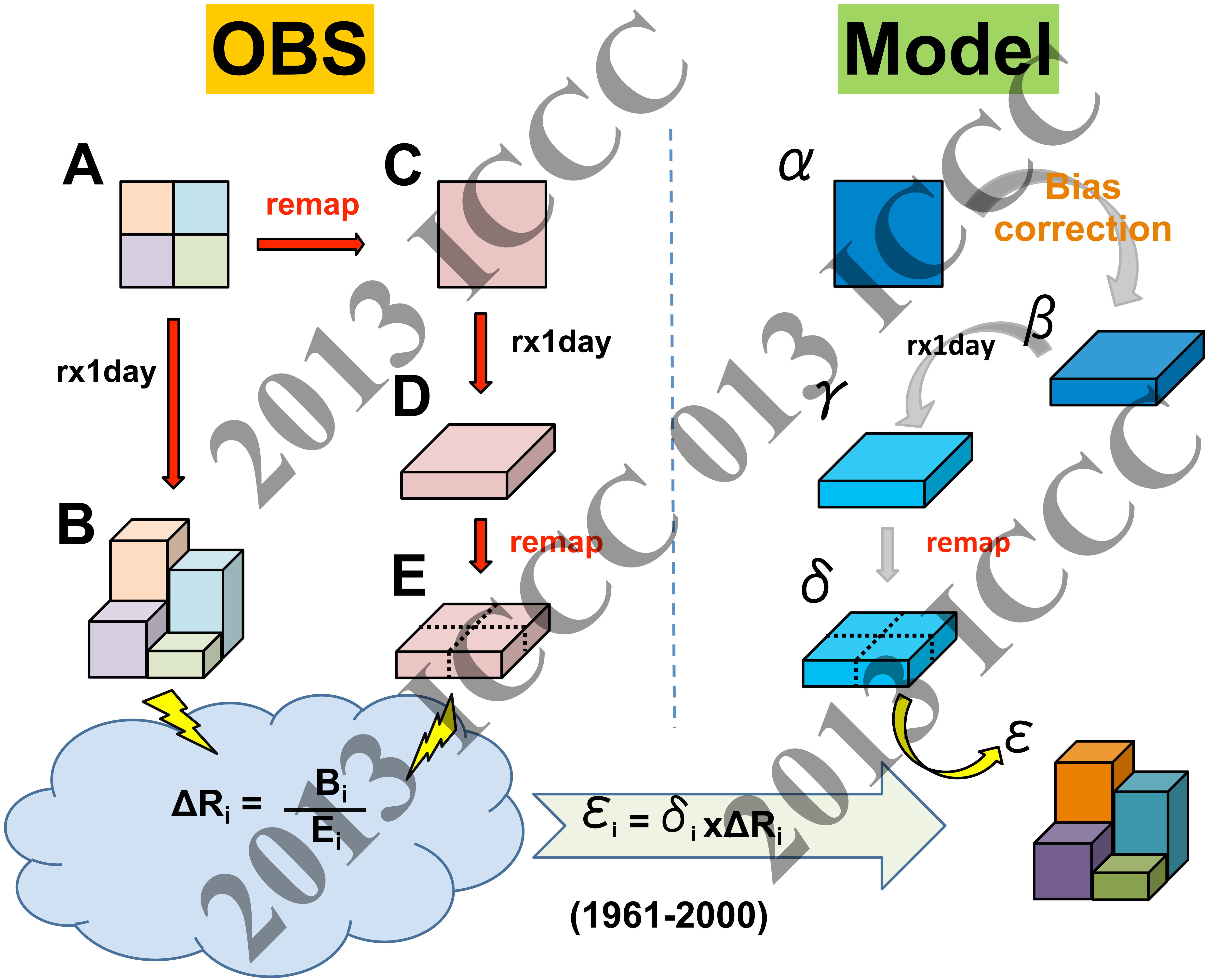


2013 ICCC 2013 ICCC 2013 ICCC 2013 ICCC

Downscaled model ensemble mean RX1day



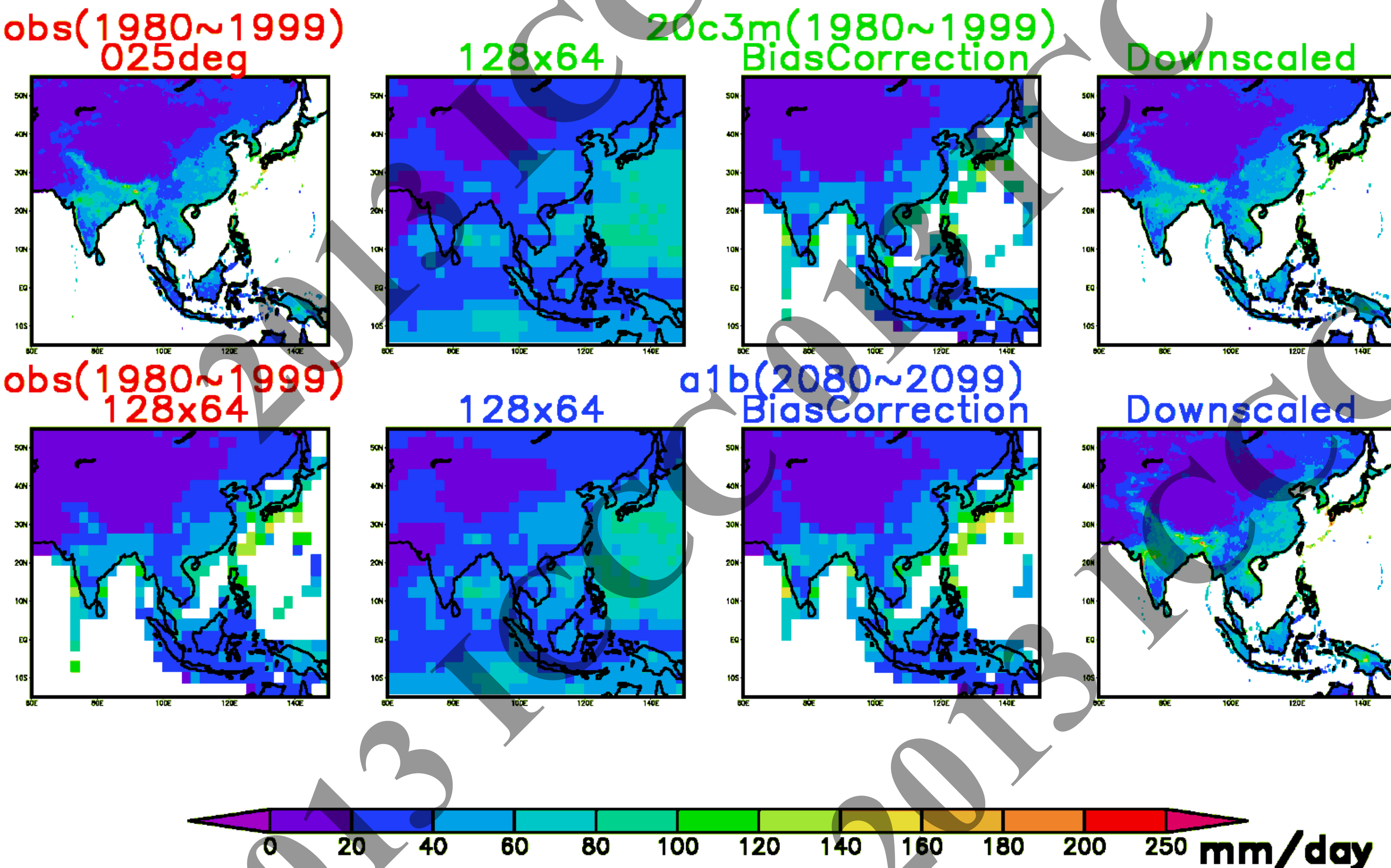
2013 ICCC



OBS
Model
A
remap
C
rx1day
rx1day
D
B
remap
E
α
Bias correction
β
rx1day
γ
remap
δ
ε
$\Delta R_i = \frac{B_i}{E_i}$
$\varepsilon_i = \delta_i \times \Delta R_i$
(1961-2000)

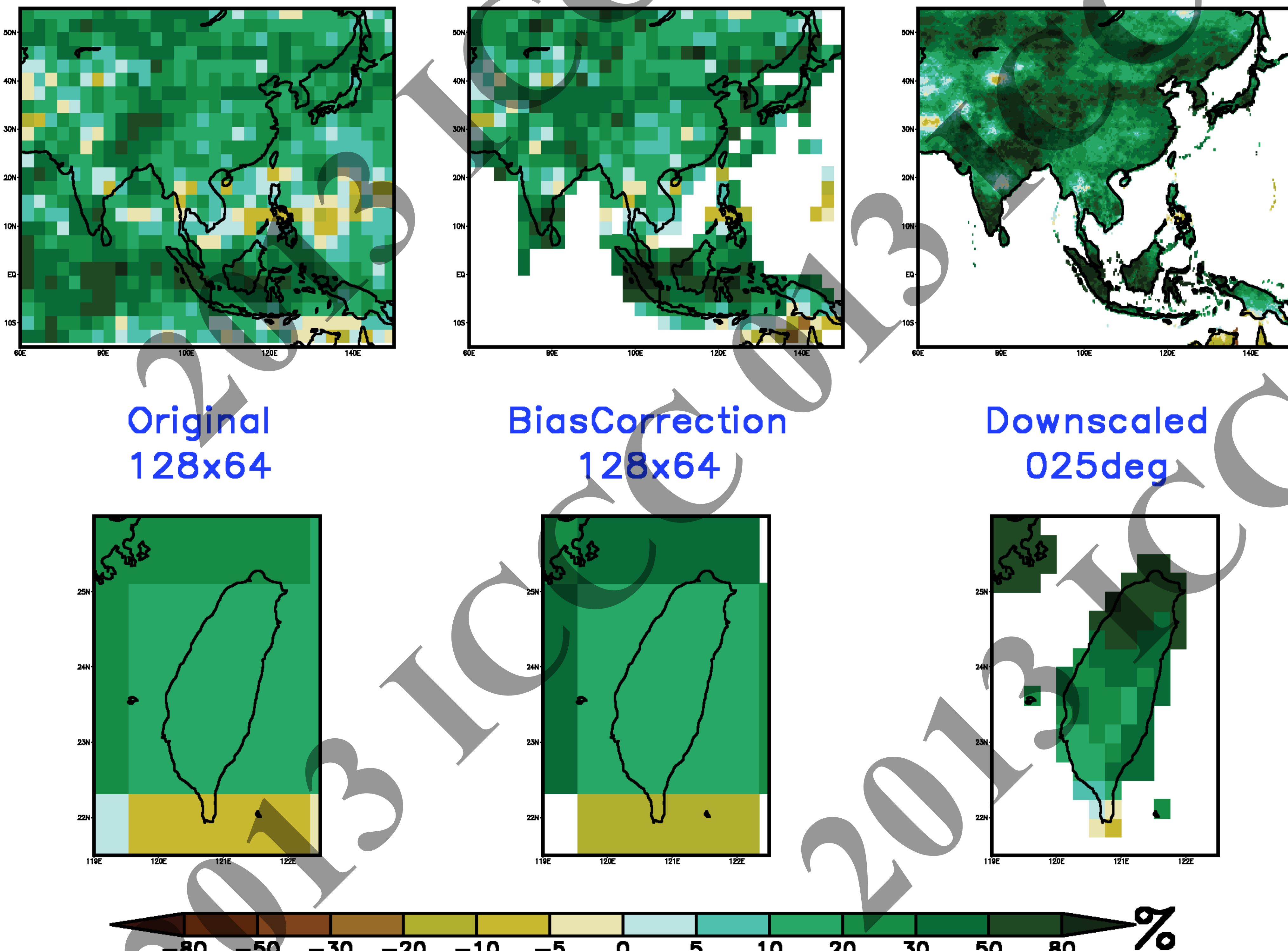
2013 ICCC

rx1day mri_cgcm2_3_2a



2013 ICCC

miroc3_2_medres rx1day Change (%)

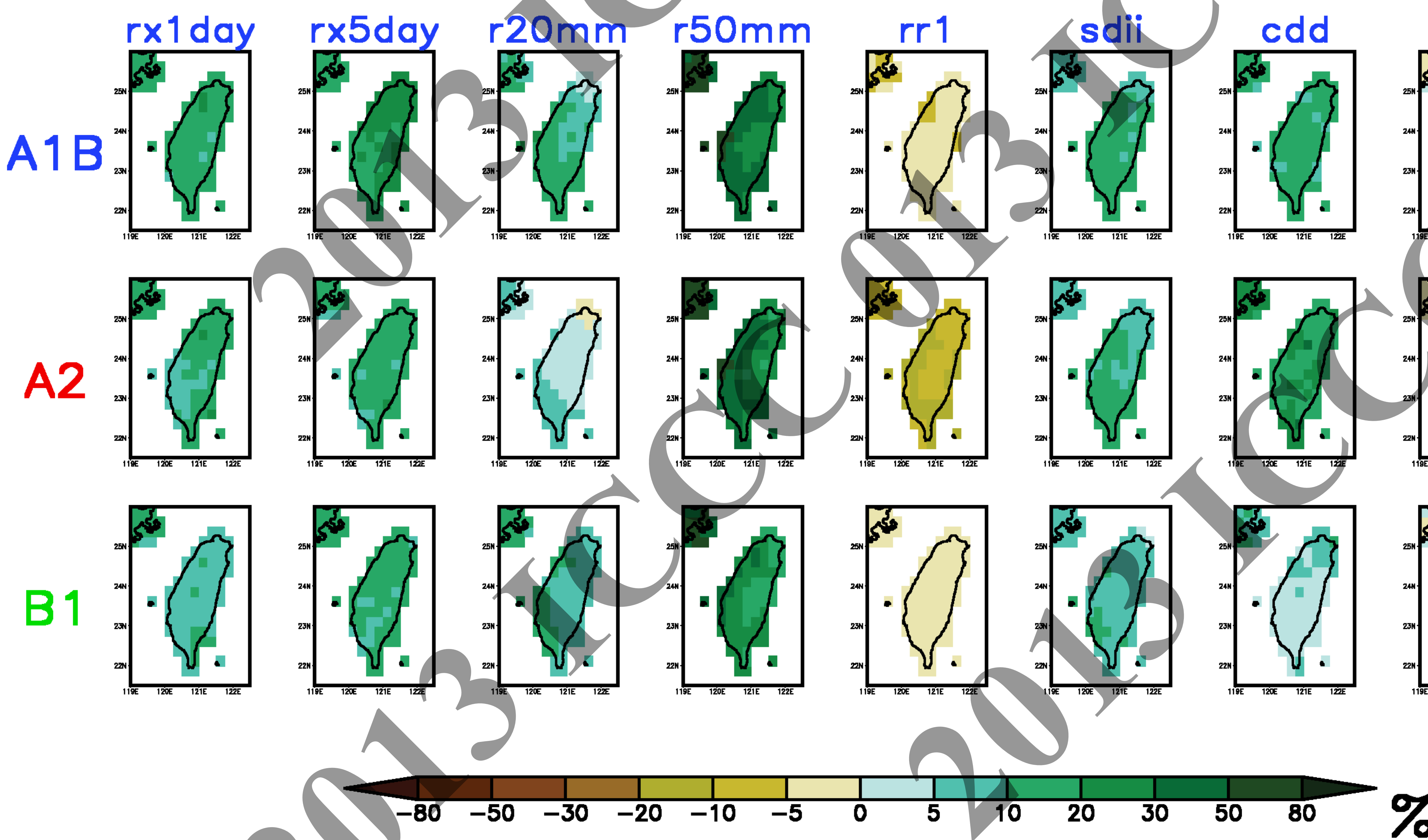


2013 ICCC

2013 ICCC 2013 ICCC 2013 ICCC 2013 ICCC

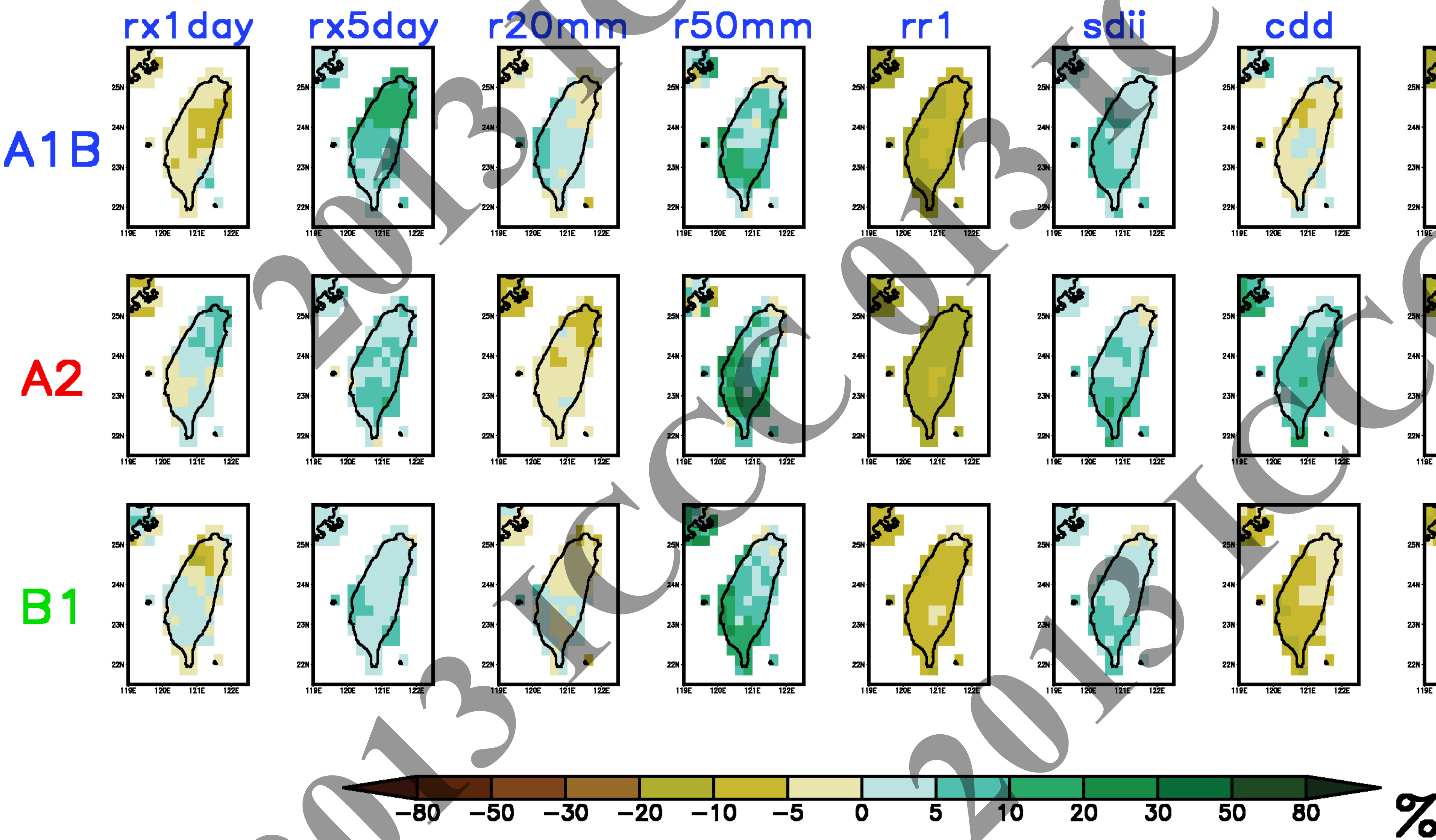
Extreme Indices		unit
RX1DAY	Highest one day precipitation amount per time period	mm/day
RX5DAY	Highest five-day precipitation amount per time period	mm/day
R20MM	Heavy precipitation days index per time period	day
R50MM	Very heavy precipitation days index per time period	day
RR1	Wet days index per time 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 (%)



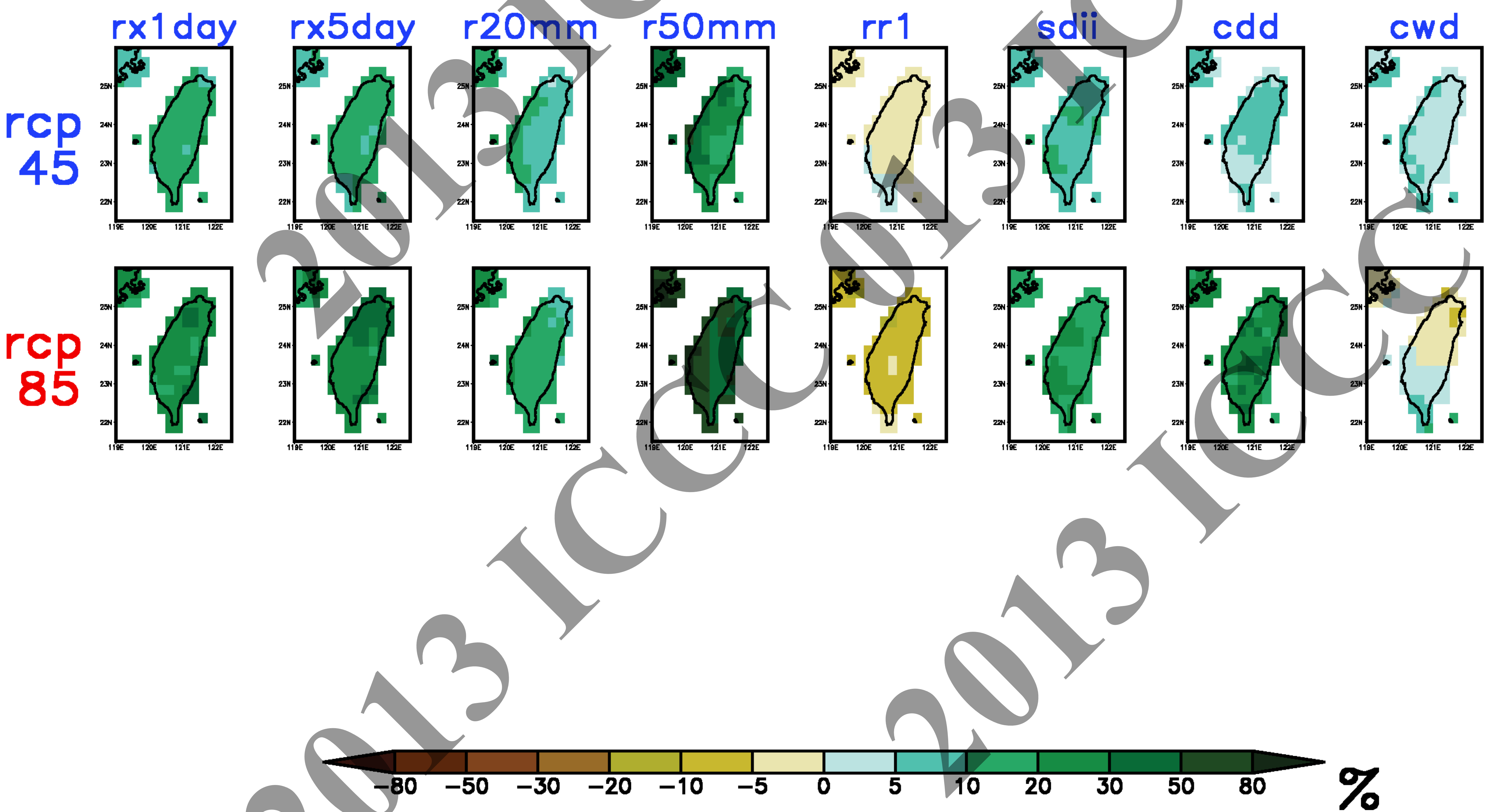
2013 ICCC

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



2013 ICCC

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



2013 ICCC
2013 ICCC
2013 ICCC
2013 ICCC

Summary and Concluding Remarks (mean)

- Must consider the other major uncertainties (emission scenario, model, etc.) regarding future climate in addition to downscaling to local scale. Probabilistic projection better represent the uncertainty.
- Large resources are needed for dealing with all the uncertainties using dynamical downscaling approach. Statistical approach is a relatively simple alternative.
- Although the uncertainties can be more easily included with statistical downscaling approach, one should aware about the assumption, limitation and caveats of this type of climate information regionalization tool:
  - long-term high-resolution observation availability
  - statistical relationship between model data and observation remains valid for periods outside calibration period
  - only limited area with local change passed statistical significance test

  ....

2013 ICCC 2013 ICCC 2013 ICCC 2013 ICCC

Summary and Concluding Remarks (extreme)

- Spatial scale of daily precipitation data should be carefully considered in the extreme analysis, especially for model validation and comparison.
- While the model precipitation parameterization play important role in determining the simulated extreme daily rainfall amount, the spatial scale dependence of different climate models can be removed by up-scaling the high-resolution models or alternatively by downscaling the model simulation to higher resolution based on observational spatial statistics.
- The majority (not all) of CMIP/IPCC models still tends to underestimate extreme daily precipitation.
- Regionalization of CMIP model simulations and projections on the high-impact weather and climate extremes should be welcomed by climate impact studies which often required detailed local information.
- Limitations: whether the present observed extreme statistics between different spatial scales stand in the future.

2013 ICCC 2013 ICCC 2013 ICCC 2013 ICCC