Regionalization and Uncertainty of Future Taiwan Climate Change Projection Based on CMIP5 Statistical Downscaling

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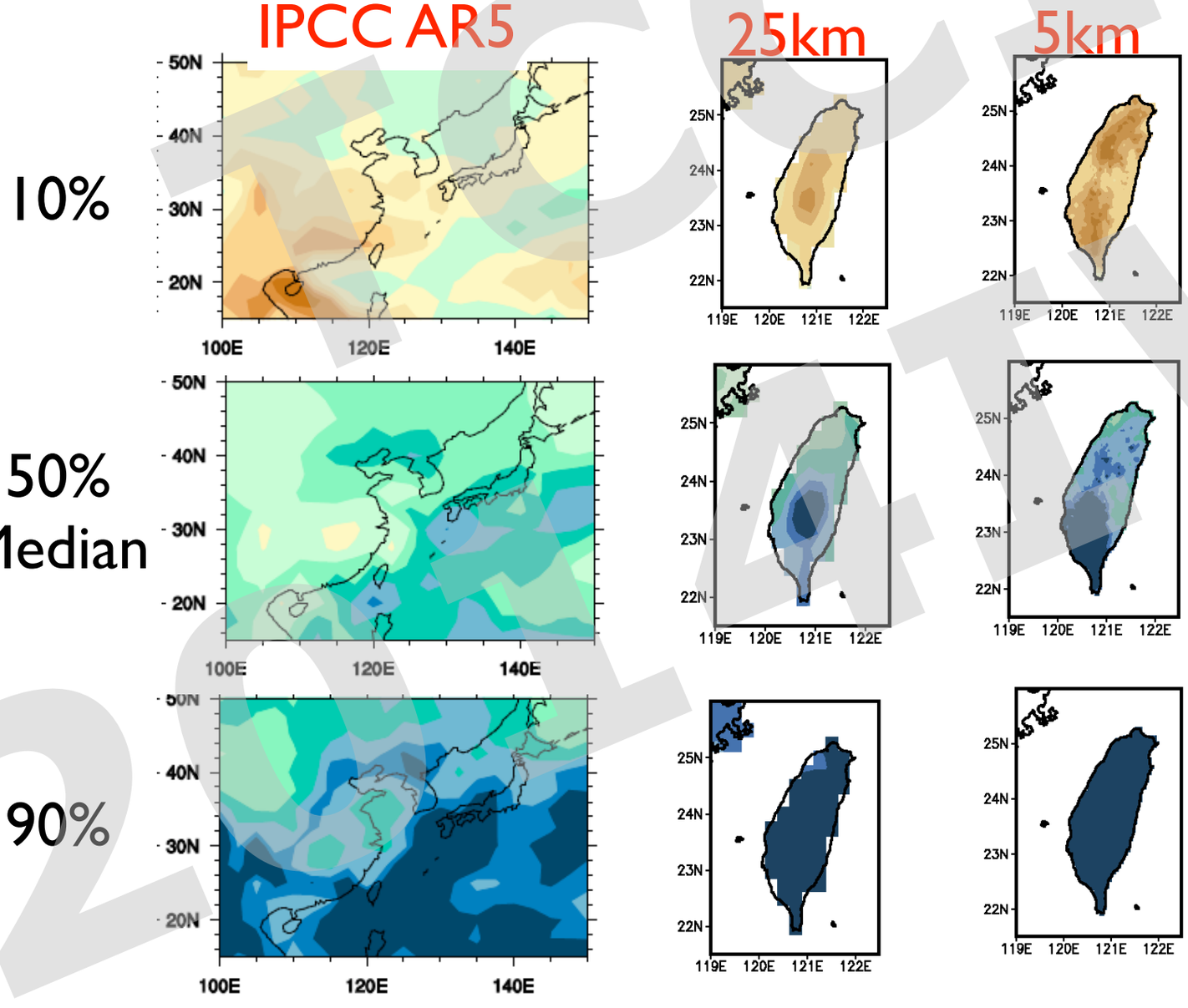
NCDR Taiwan Climate Change Projection and Information Platform Project Team

2080-2099 Projected JJA ΔP, RCP8.5



- Why do we need regionalization ?
- Why statistical downscaling and How?
- Update with CMIP5
- Projection uncertainties and sources
- Summary

Why do we need downscaling?

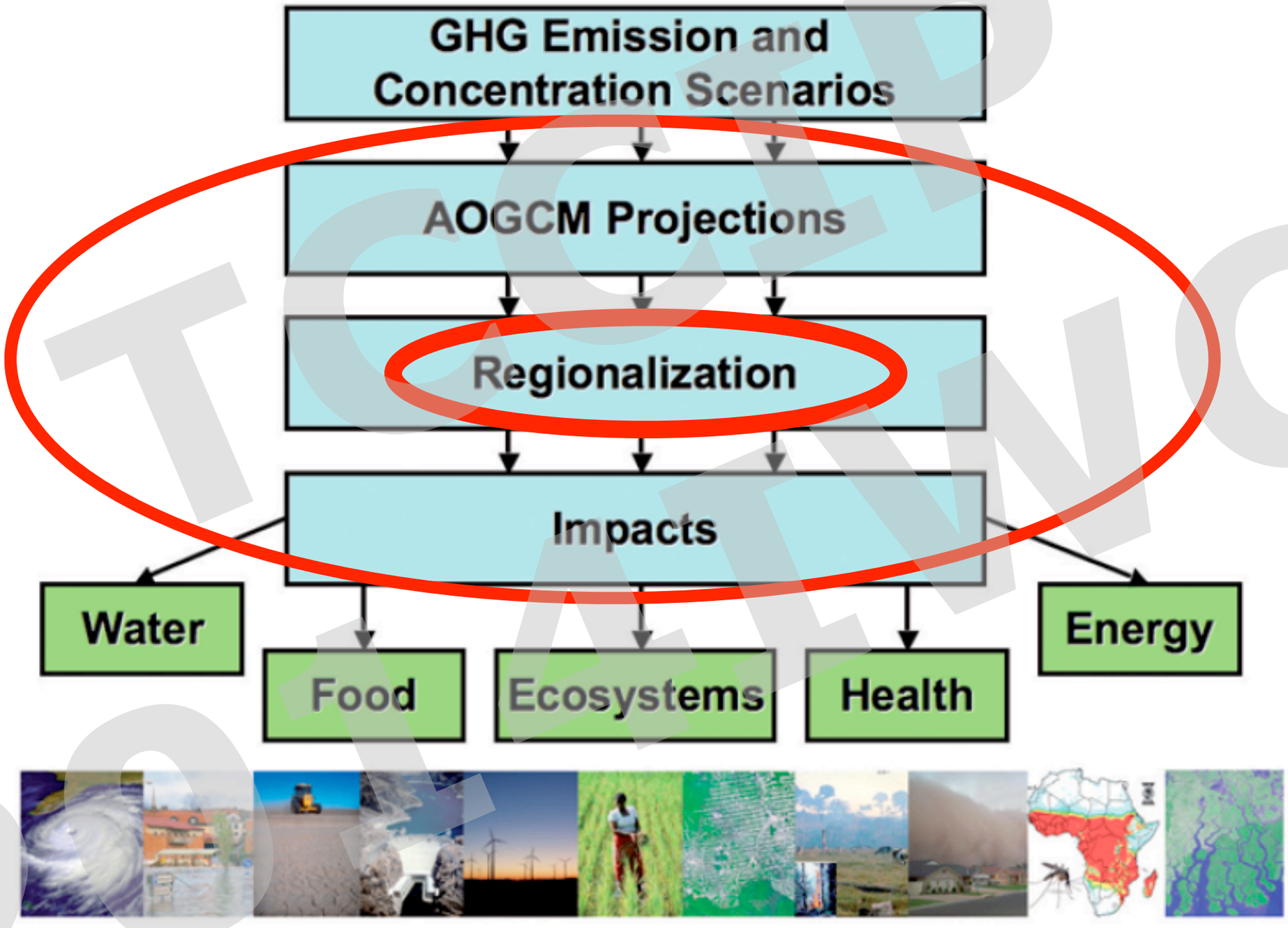
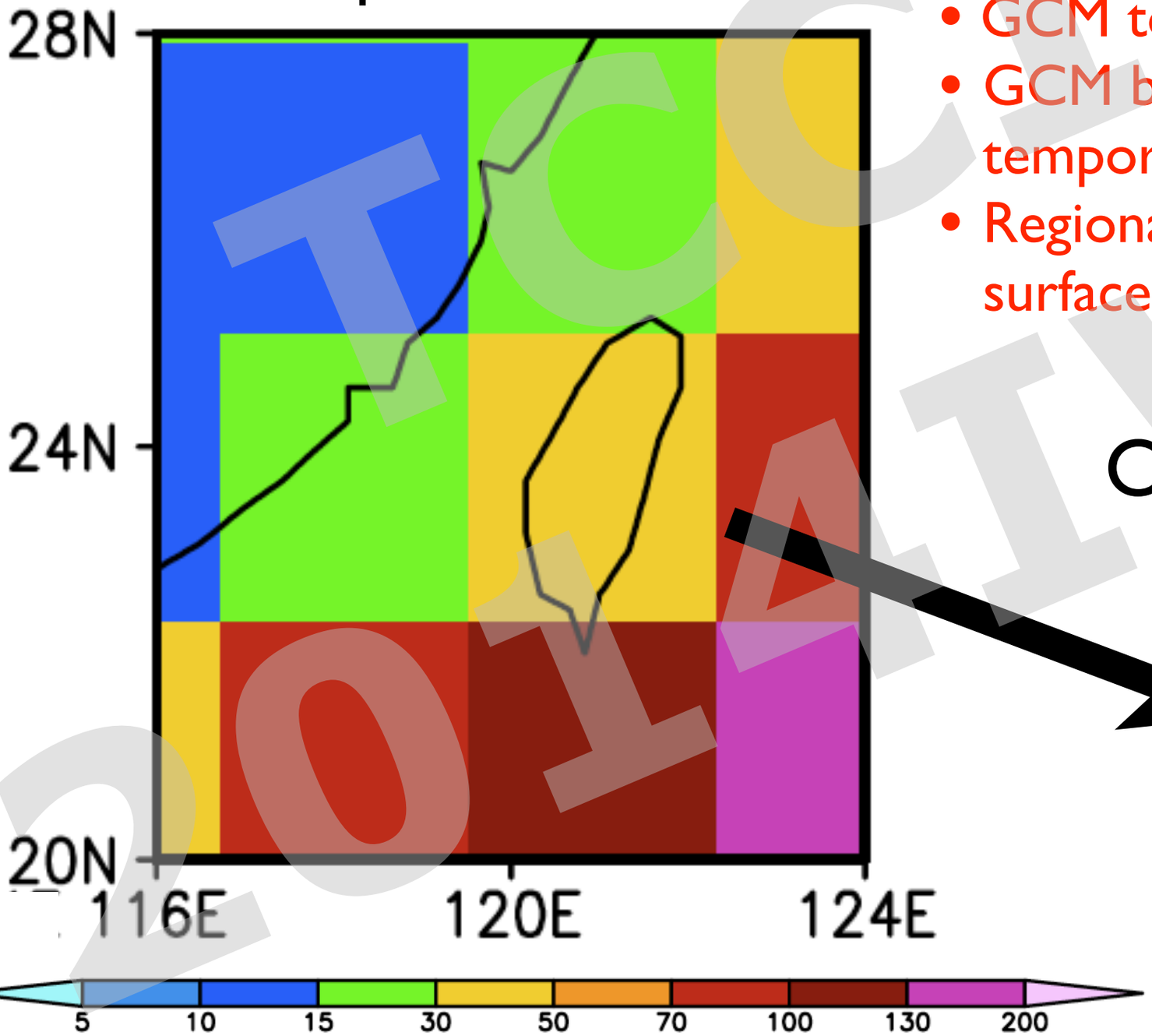


Figure 3 — Schematic depiction of the steps involved in the production of climate change information usable for impact assessment work via regionalization methods

Source: Giorgi (2008)

Why do we need downscaling?

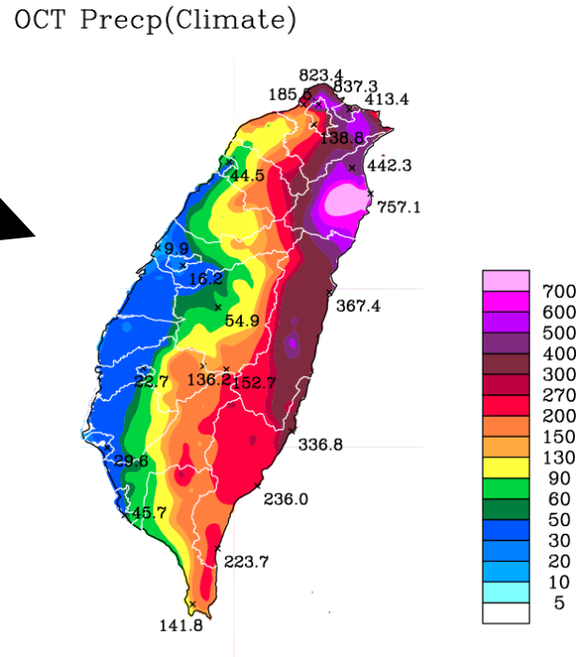
GCM (~300 km)
Precipitation October



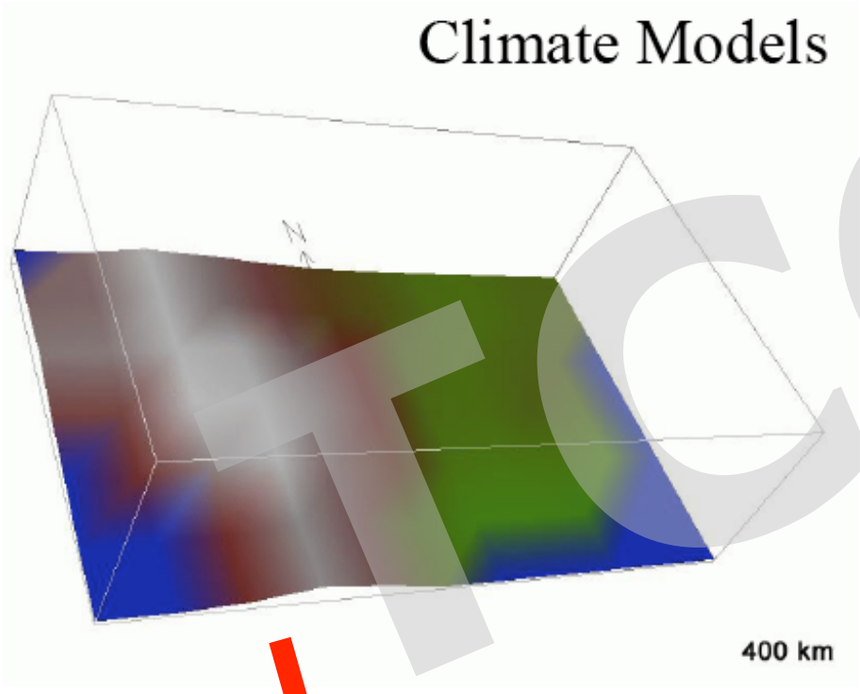
Problems:

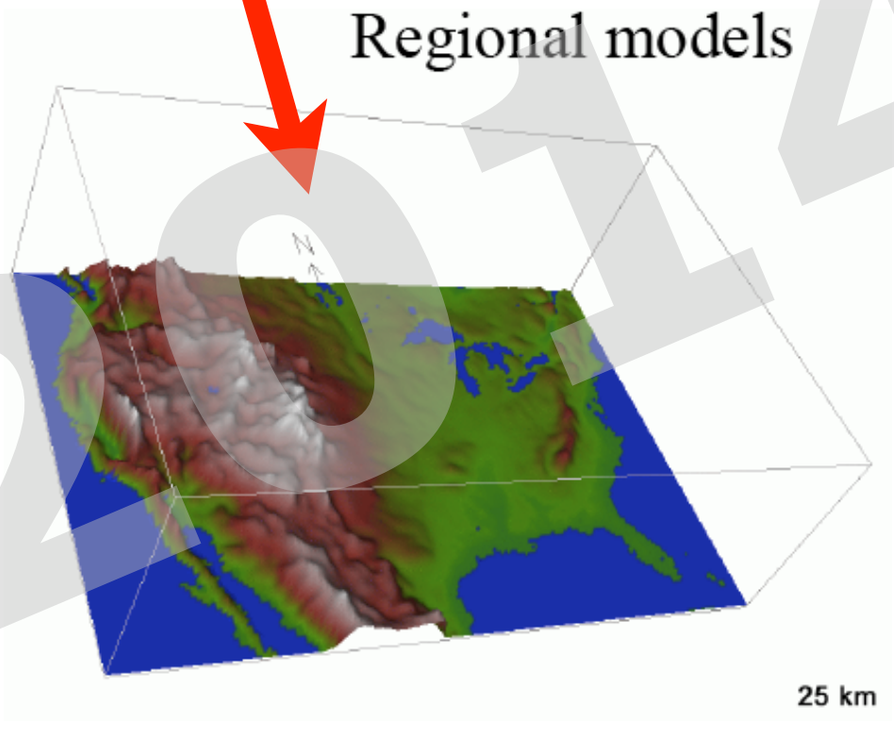
- GCM too coarse for local assessment
- GCM biases in climatology (spatially and temporally)
- Regional climate variability (topography, surface landscapes, coastlines)

Observation (~5km)



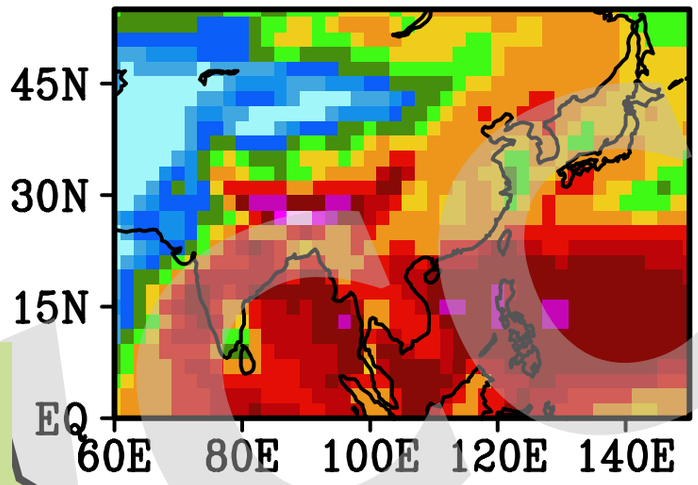
Dynamical Downscaling



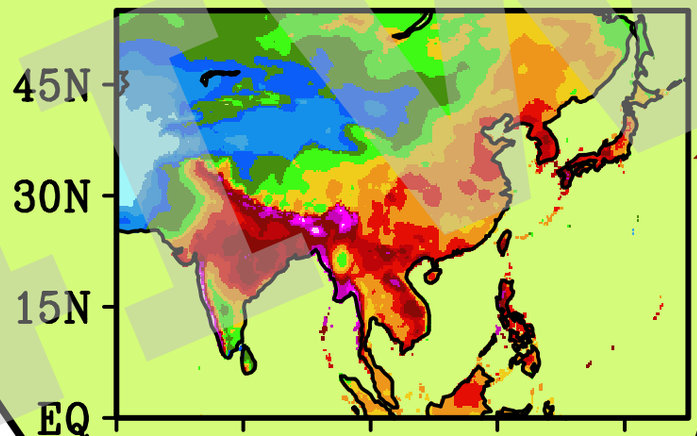


Statistical Downscaling

Climate Model

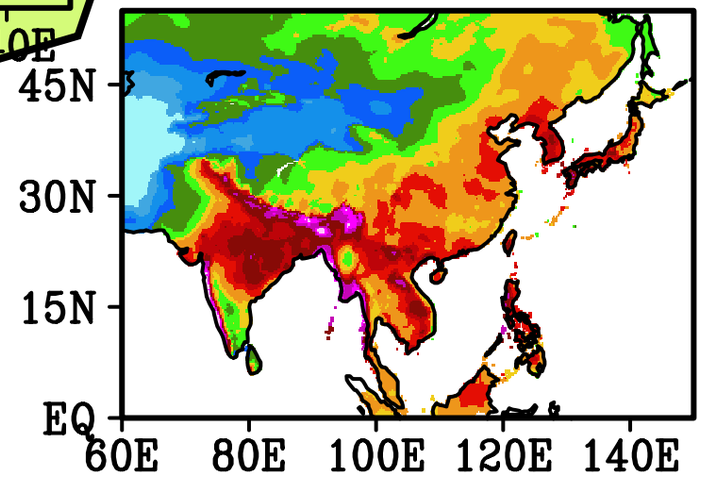


High Resolution Observation



Develop transfer function

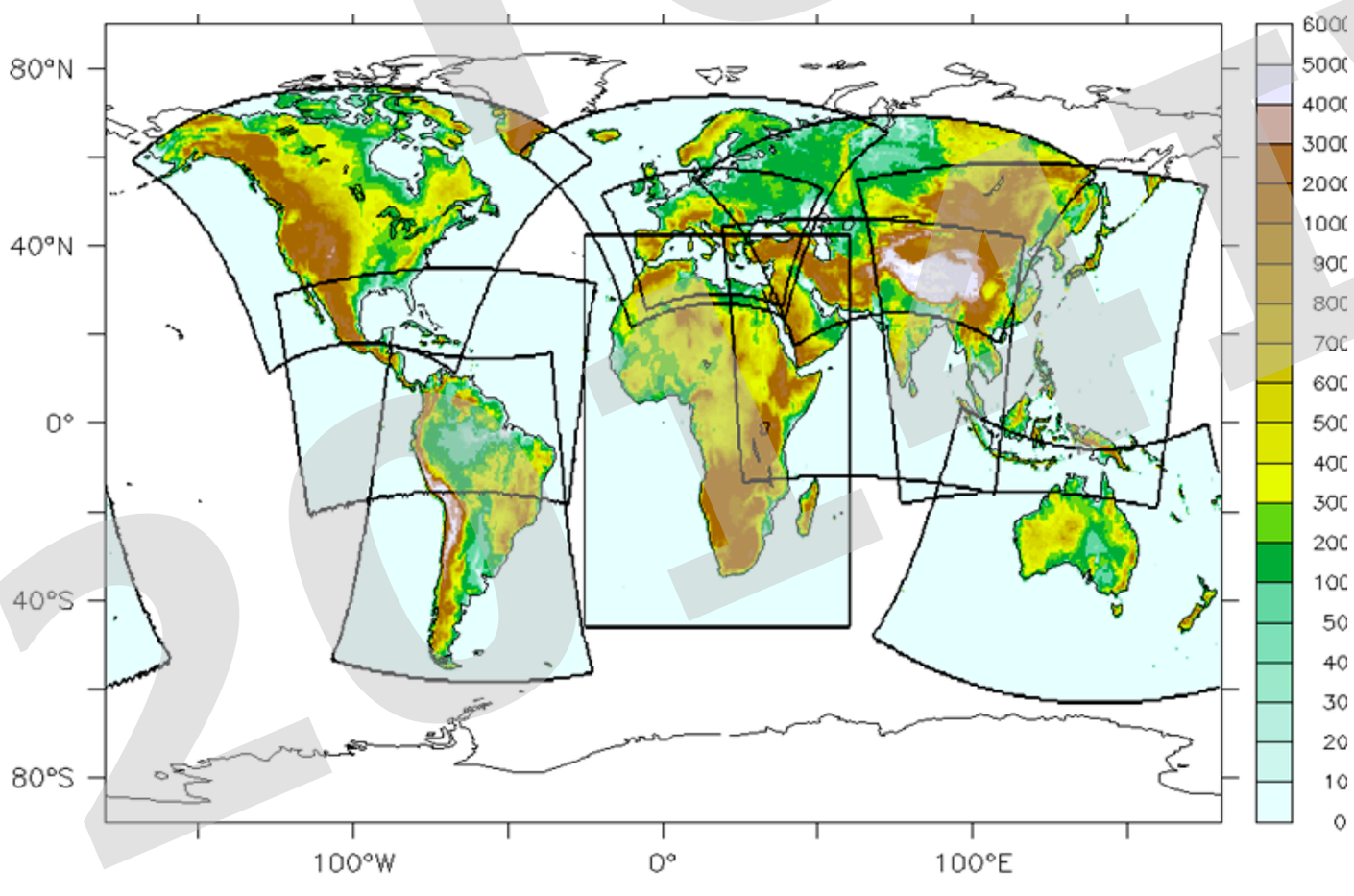
Downscaled

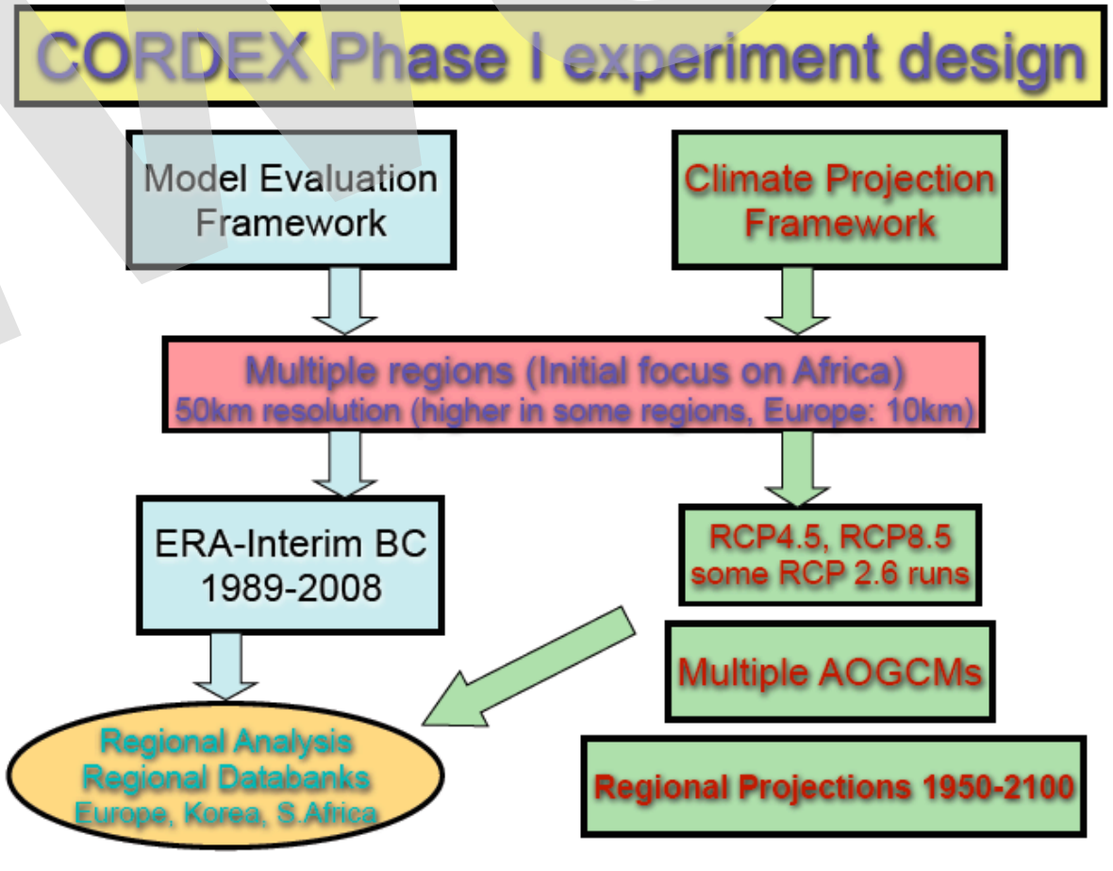


Dynamical downscaling (RCMs)

Dynamical downscaling required large resources to cover all scenarios, different GCM/RCM sensitivity

WCRP CORDEX





Why statistical downscaling?

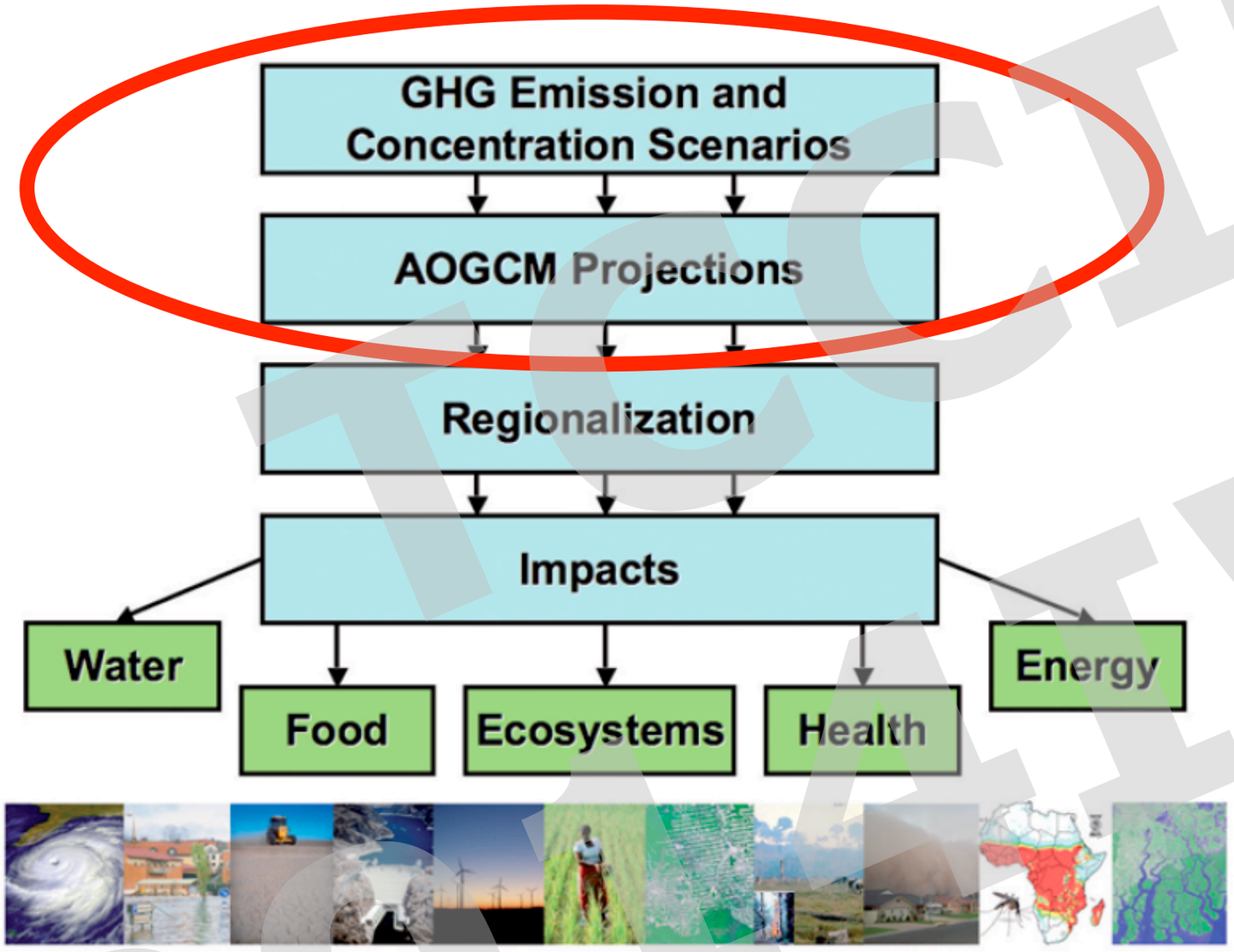
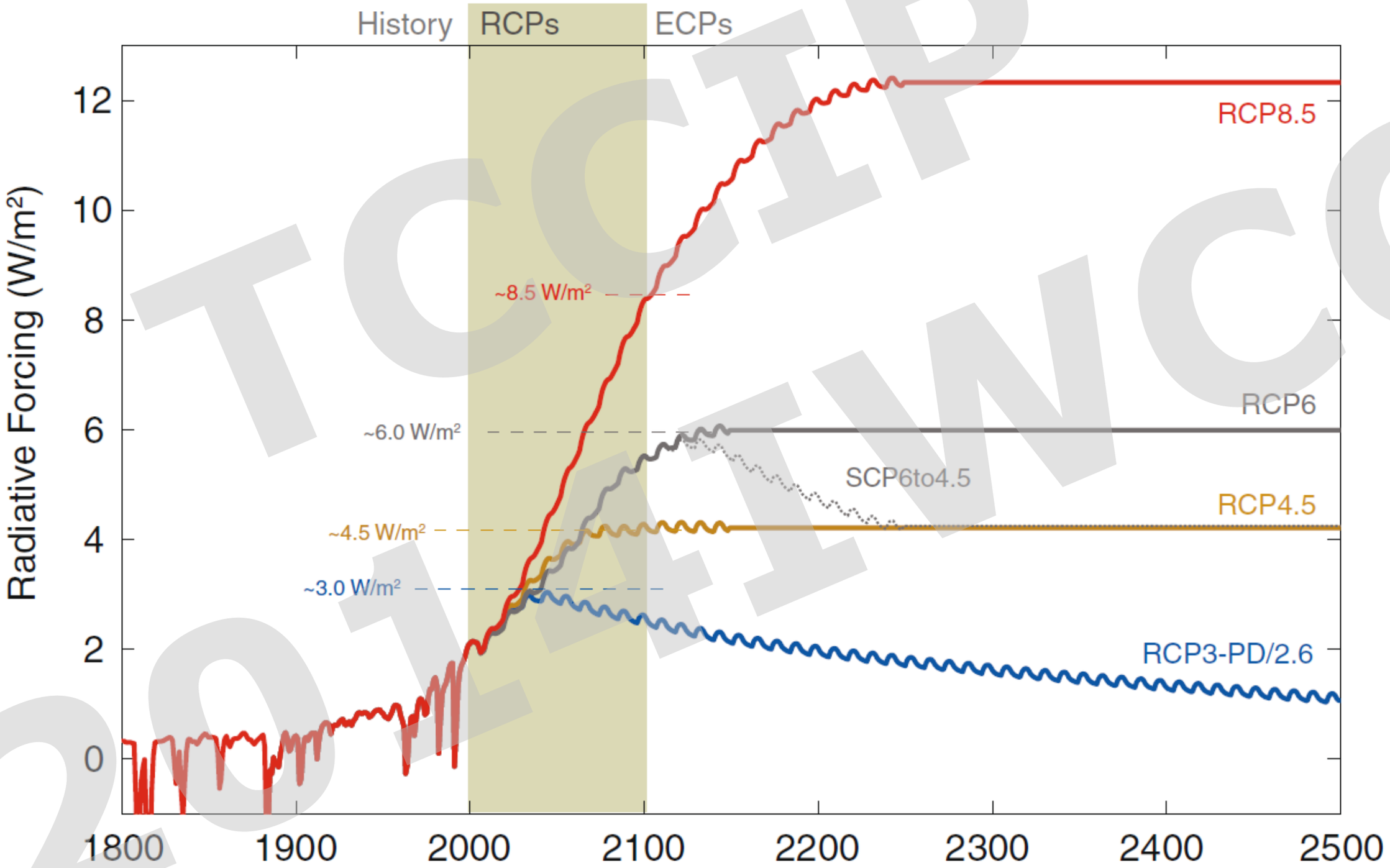


Figure 3 — Schematic depiction of the steps involved in the production of climate change information usable for impact assessment work via regionalization methods

Source: Giorgi (2008)

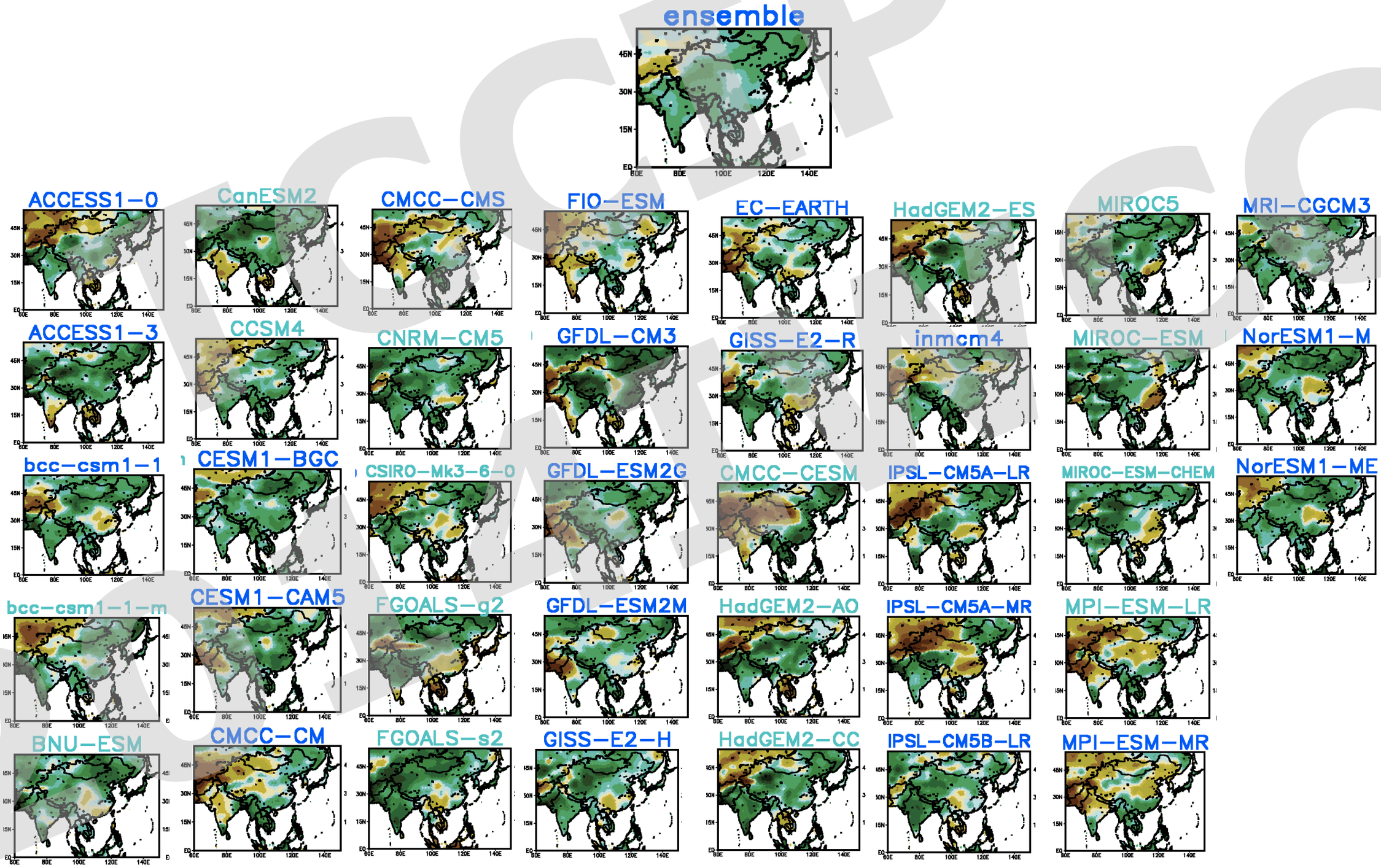
- Uncertainties in future greenhouse gas and aerosol emissions
- Uncertainties in global and regional climate sensitivity, due to differences in the way physical processes and feedbacks are simulated in different models
- Regionalization with statistical approach doesn't need extensive resources and, therefore, possible to cover all the uncertainties and produce probabilistic projection.

Uncertainty from AR5 Emission Scenarios



Uncertainty from Global Climate Models

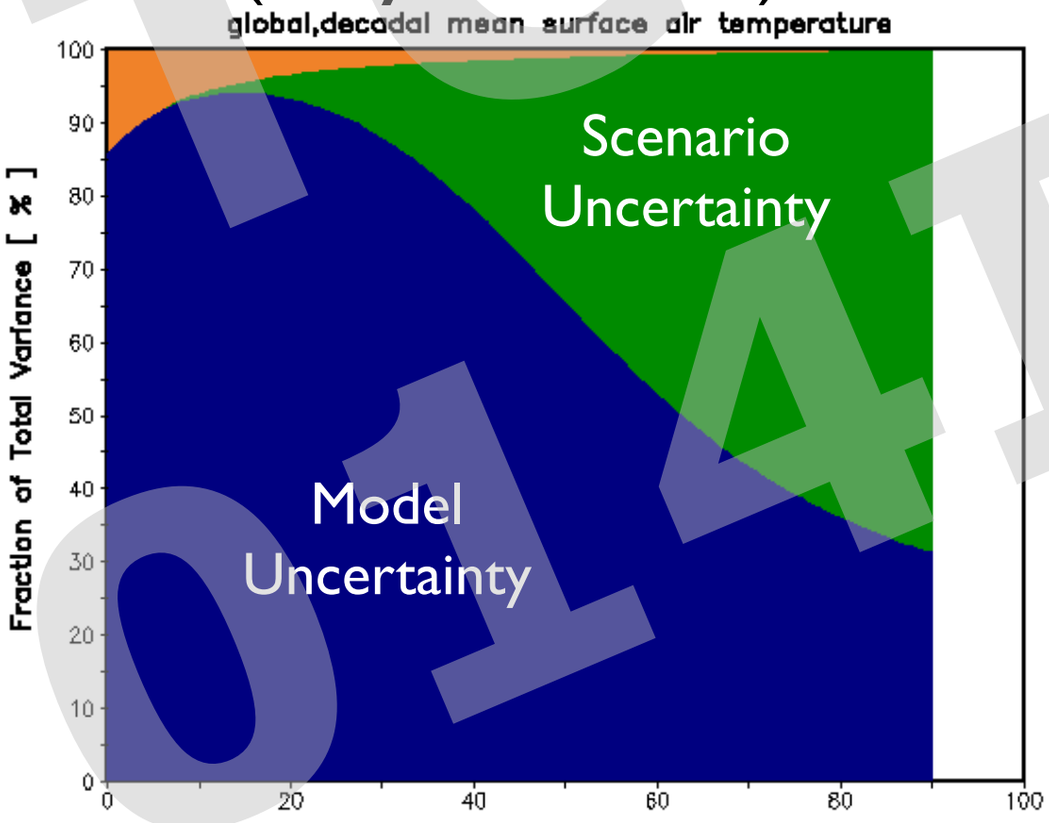
Summer precipitation change(%) with CMIP5 models under RCP8.5 scenario



Uncertainties Assessment (Hawkin and Sutton, 2009)

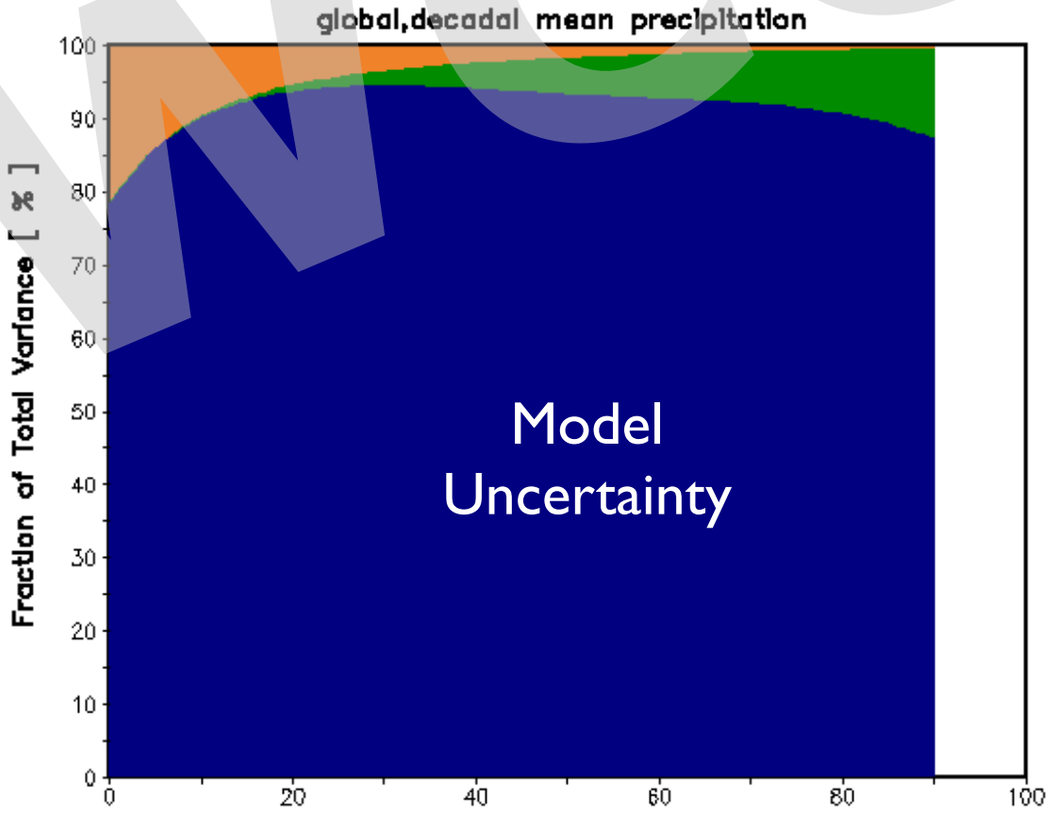
Fraction of Total Variance Plot (Scenario, Model, Internal Variability)

Global mean
Surface Air Temperature
(20 year mean)



Lead time (years from 2000)

Global mean
Precipitation
(20 year mean)



Lead time (years from 2000)

(Dynamical-) Statistical Downscaling

Simple Statistical Downscaling:
Bias Correction Spatial Downscaling (BCSD)

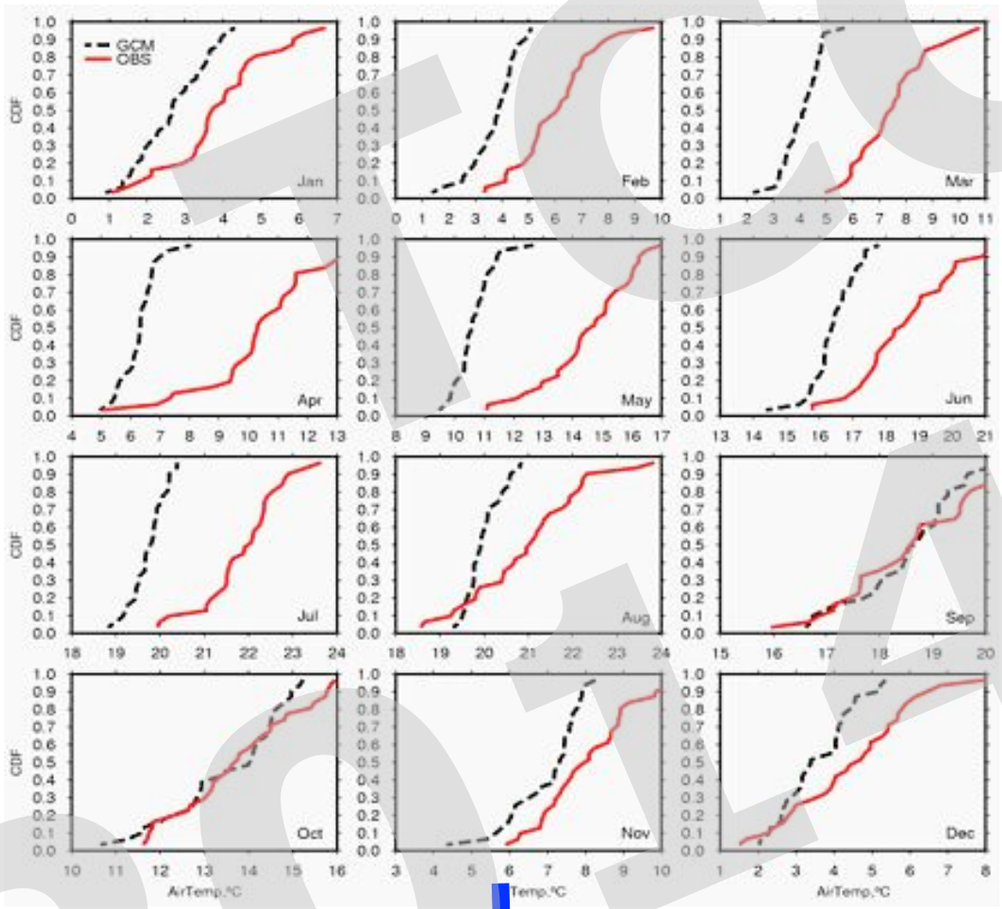
Wood et al. 2004, and Maurer 2007

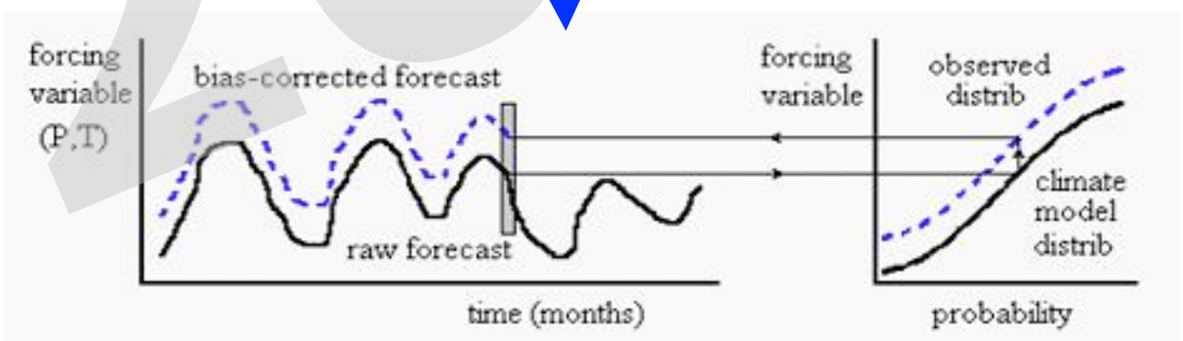
- Aggregate gridded OBS to GCM resolution
- Remove trend (if the trend is significant)
- Generate CDF of observed and GCM data
  - Q-Q mapping approach
  - limitation on extrapolation
- Add trend back in
- Resample/interpolate to finer resolution
- Apply spatial factor to account for subgrid topography

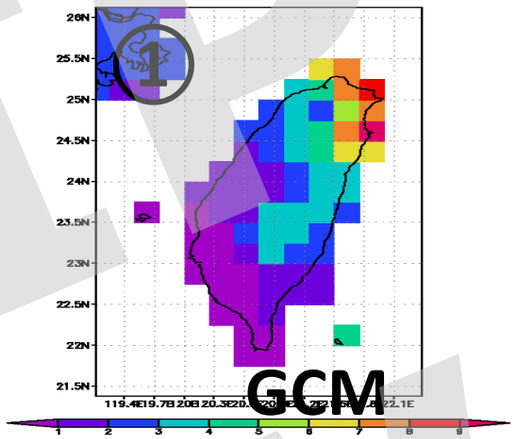
(Dynamical-) Statistical Downscaling

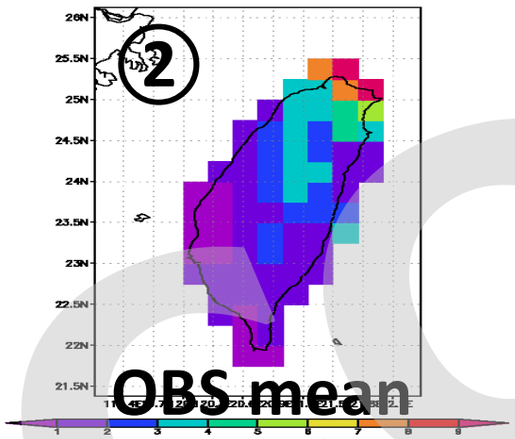
Statistical downscaling and bias correction by cumulative distribution function and interpolation

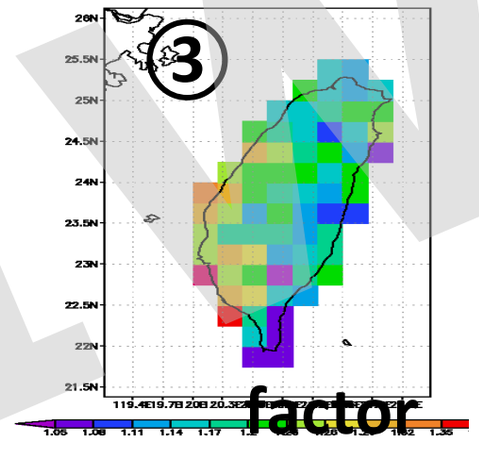
Wood et al. 2004, and Maurer 2007

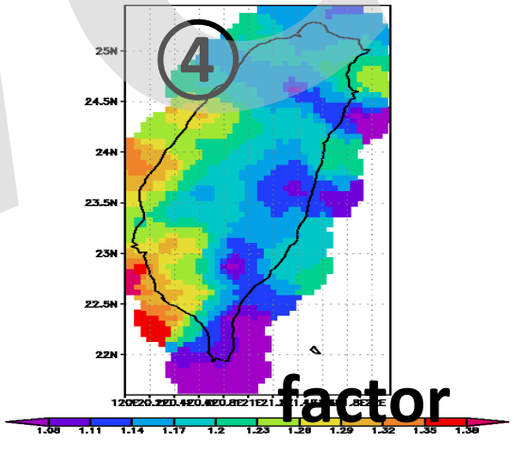


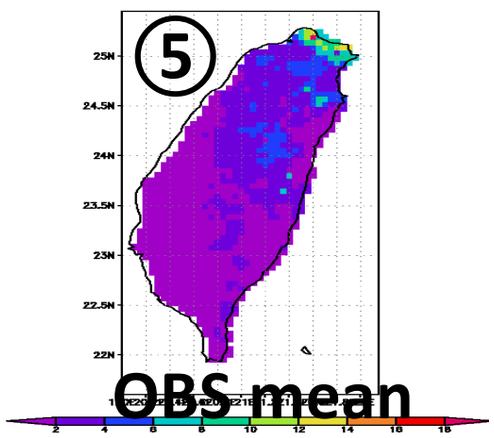


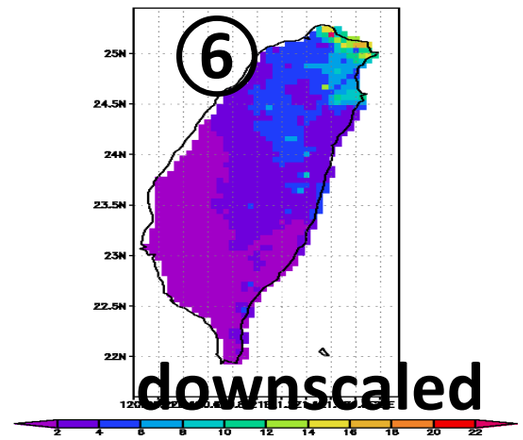












CMIP5 experiments

historical

RCP2.6, 4.5, 6.0, 8.5

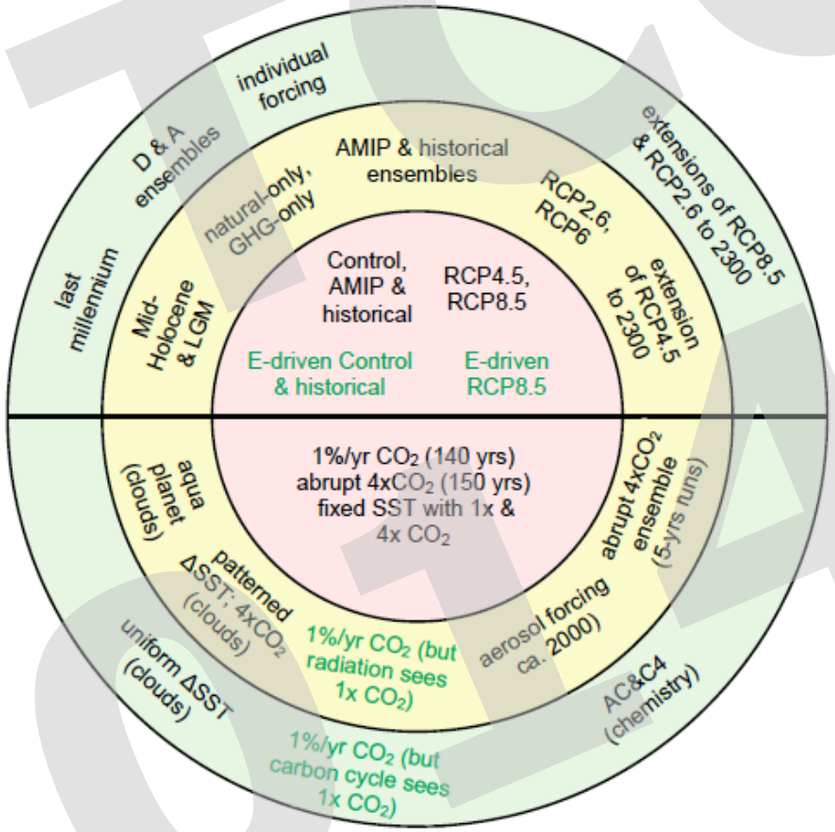


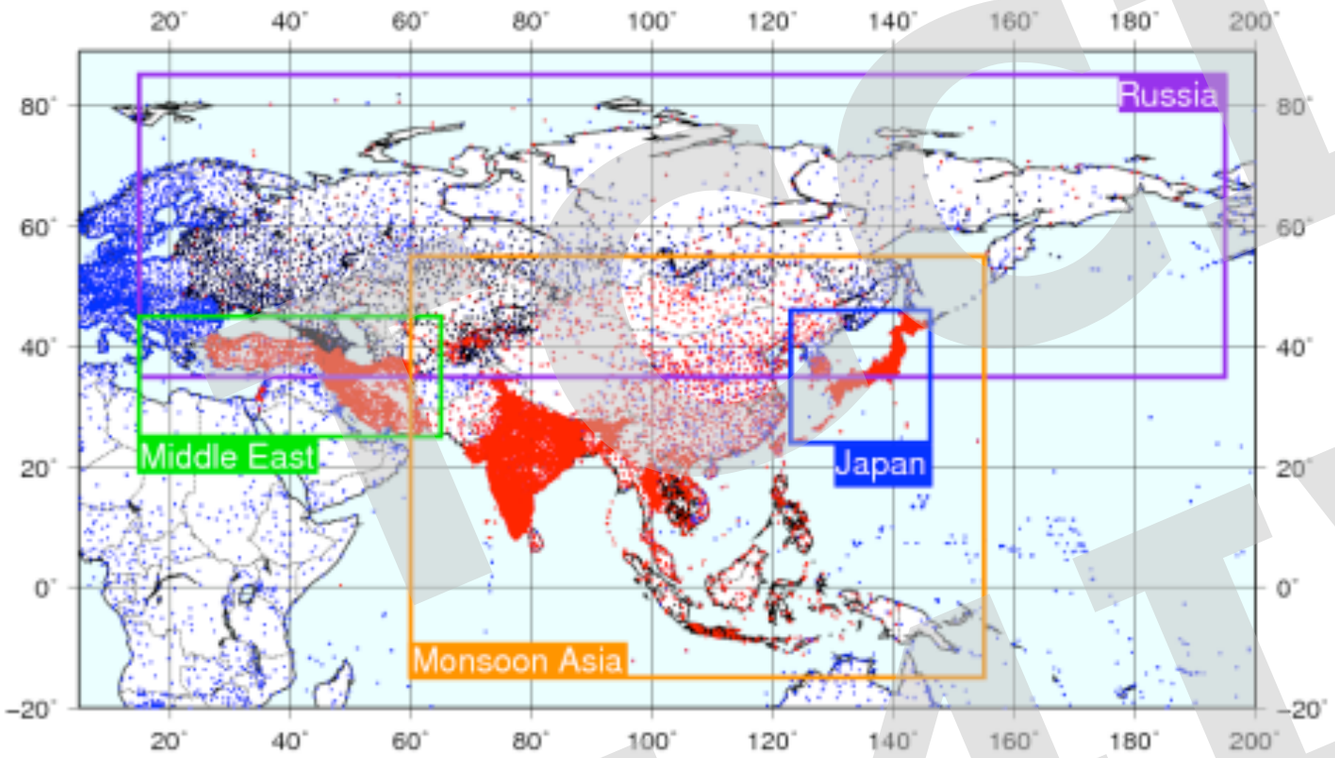
FIG. 2. Schematic summary of CMIP5 long-term experiments with tier 1 and tier 2 experiments organized around a central core. Green font indicates simulations to be performed only by models with carbon cycle representations. Experiments in the upper hemisphere are suitable either for comparison with observations

CMIP5 models (29 centers, >50 model versions)

Modeling Center	Model	Institution	terms of use
BCC	BCC-CSM1.1 BCC-CSM1.1(m)	Beijing Climate Center, China Meteorological Administration	unrestricted
CCCma	CanAM4 CanCM4 CanESM2	Canadian Centre for Climate Modelling and Analysis	unrestricted
CMCC	CMCC-CESM CMCC-CM CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici	non-commercial only
CNRM-CERFACS	CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	non-commercial only
COLA and NCEP	CFSv2-2011	Center for Ocean-Land-Atmosphere Studies and National Centers for Environmental Prediction	unrestricted
CSIRO-BOM	ACCESS1.0 ACCESS1.3	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)	non-commercial only
CSIRO-QCCCE	CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence	non-commercial only
EC-EARTH	EC-EARTH	EC-EARTH consortium	non-commercial only
FIO	FIO-ESM	The First Institute of Oceanography, SOA, China	non-commercial only
GCESS	BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University	unrestricted
INM	INM-CM4	Institute for Numerical Mathematics	unrestricted
IPSL	IPSL-CM5A-LR IPSL-CM5A-MR IPSL-CM5B-LR	Institut Pierre-Simon Laplace	unrestricted
LASG-CESS	FGOALS-g2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University	unrestricted
LASG-IAP	FGOALS-gl FGOALS-s2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences	unrestricted
MIROC	MIROC-ESM MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	non-commercial only
MIROC	MIROC4h MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	non-commercial only
MOHC (additional realizations by INPE)	HadCM3 HadCM3Q HadGEM2-A HadGEM2-CC HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)	unrestricted
MPI-M	MPI-ESM-LR MPI-ESM-MR MPI-ESM-P	Max Planck Institute for Meteorology (MPI-M)	unrestricted
MRI	MRI-AGCM3.2H MRI-AGCM3.2S MRI-CGCM3 MRI-ESM1	Meteorological Research Institute	non-commercial only
NASA GISS	GISS-E2-H GISS-E2-H-CC GISS-E2-R GISS-E2-R-CC	NASA Goddard Institute for Space Studies	unrestricted
NASA GMAO	GEOS-5	NASA Global Modeling and Assimilation Office	unrestricted
NCAR	CCSM4	National Center for Atmospheric Research	unrestricted
NCC	NorESM1-M NorESM1-ME	Norwegian Climate Centre	unrestricted
NICAM	NICAM.09	Nonhydrostatic Icosahedral Atmospheric Model Group	non-commercial only
NIMR/KMA	HadGEM2-AO	National Institute of Meteorological Research/Korea Meteorological Administration	unrestricted
NOAA GFDL	GFDL-CM2.1 GFDL-CM3 GFDL-ESM2G GFDL-ESM2M GFDL-HIRAM-C180 GFDL-HIRAM-C360	Geophysical Fluid Dynamics Laboratory	unrestricted
NSF-DOE-NCAR	CESM1(BGC) CESM1(CAM5) CESM1(CAM5.1, FV2) CESM1(FASTCHEM) CESM1(WACCM)	National Science Foundation, Department of Energy, National Center for Atmospheric Research	unrestricted

Require long-term high-resolution observations

APHRODITE (0.25°)



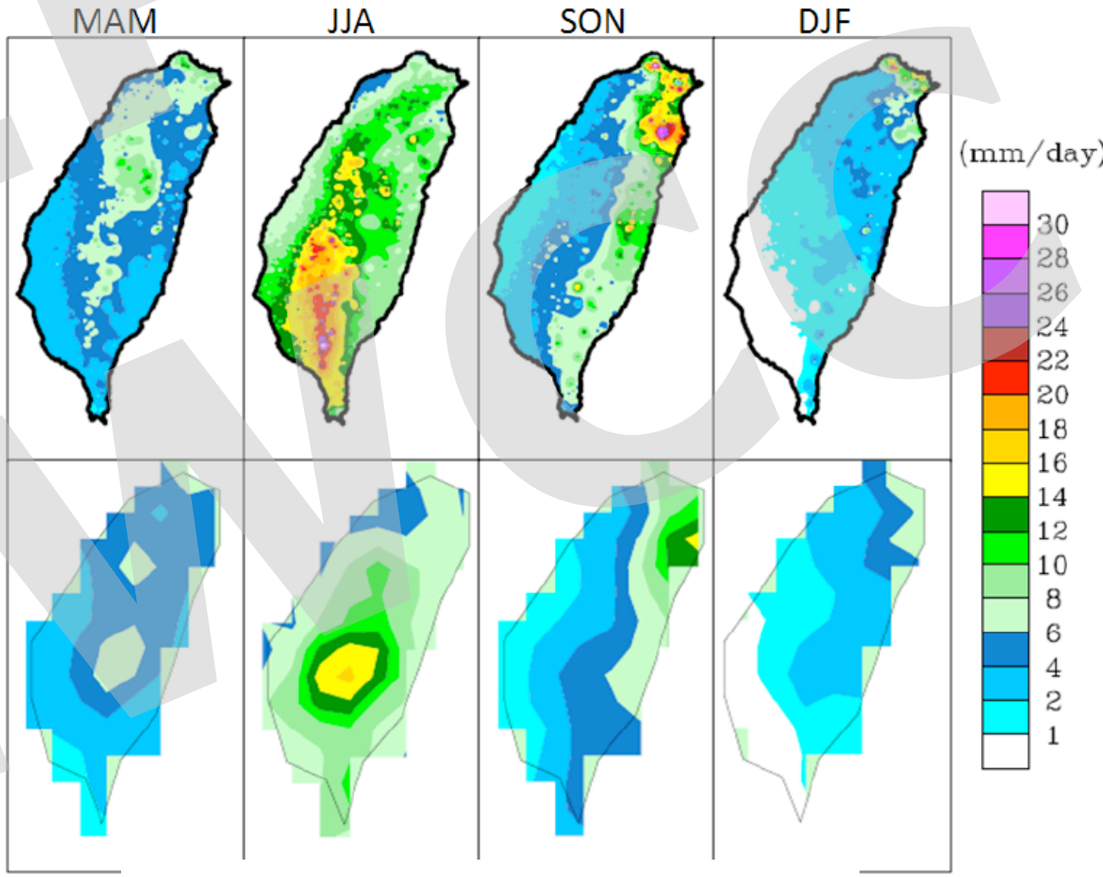
Current version, with Rain/Snow discrimination: V1101R2 Download
»Readme

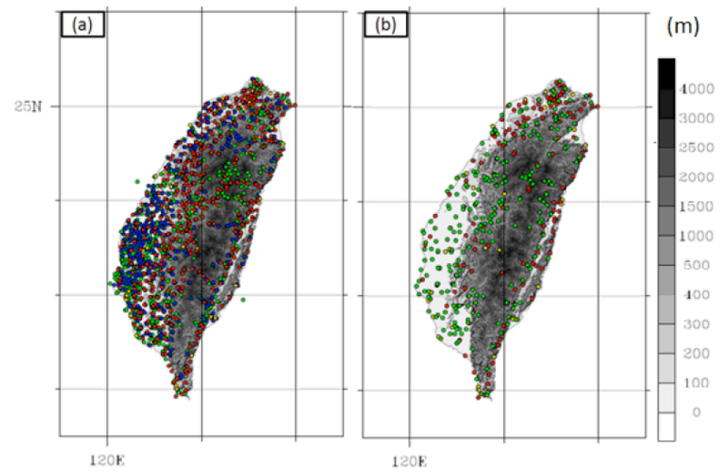
Name	Domain	Resolution	Period
Monsoon Asia (MA) (Yasutomi et al. 2011)	60°E-150°E, 15°S-55°N	0.5° and 0.25°, daily	1961-2007

AphroTemp Current version: V1204R1 Download **»Readme**

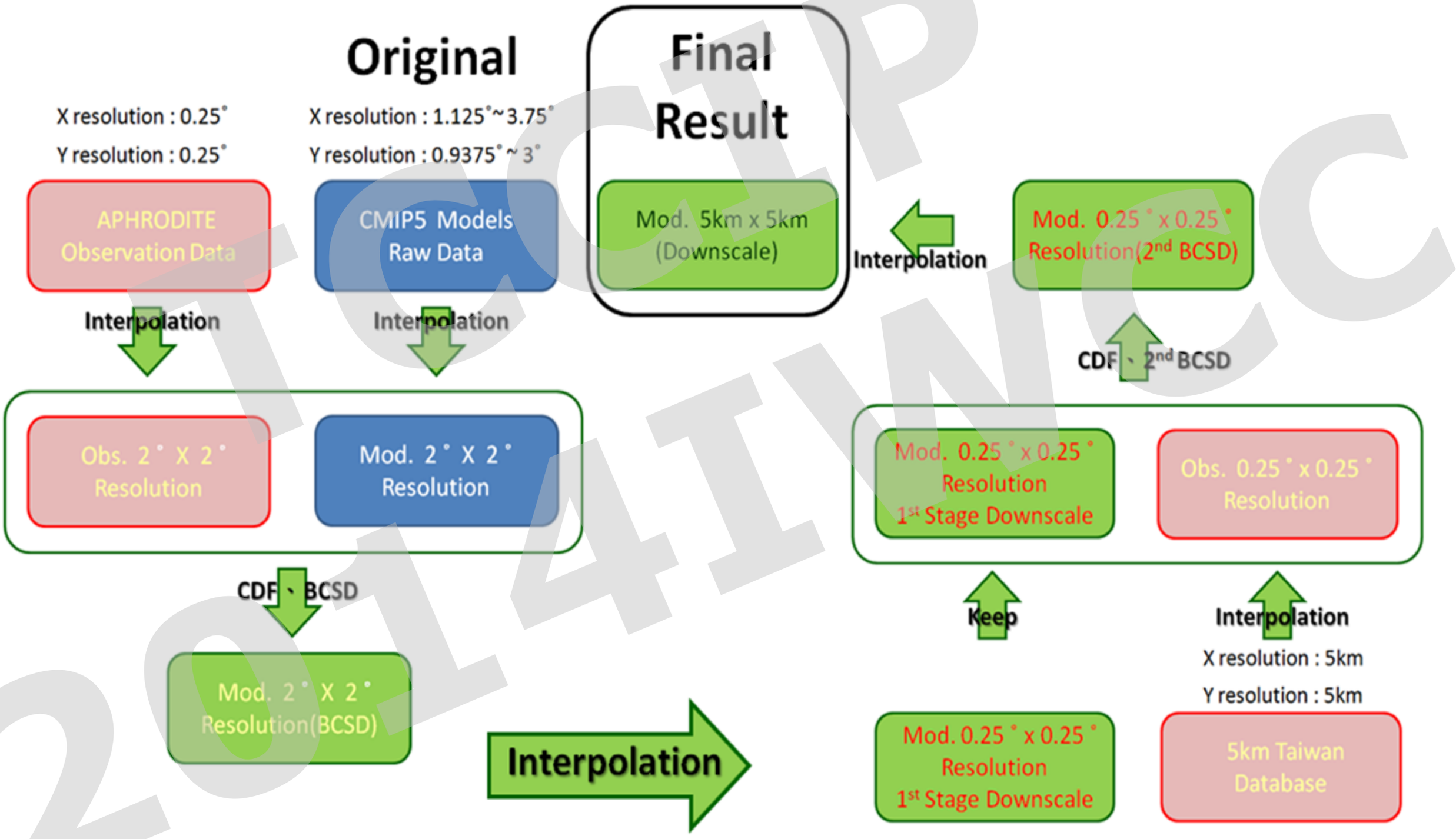
Name	Domain	Resolution	Period
Monsoon Asia (MA) (Yasutomi et al. 2011)	60°E-150°E, 15°S-55°N	0.5° and 0.25°, daily	1961-2007

New high-resolution (1~5km) gridded climate data over Taiwan





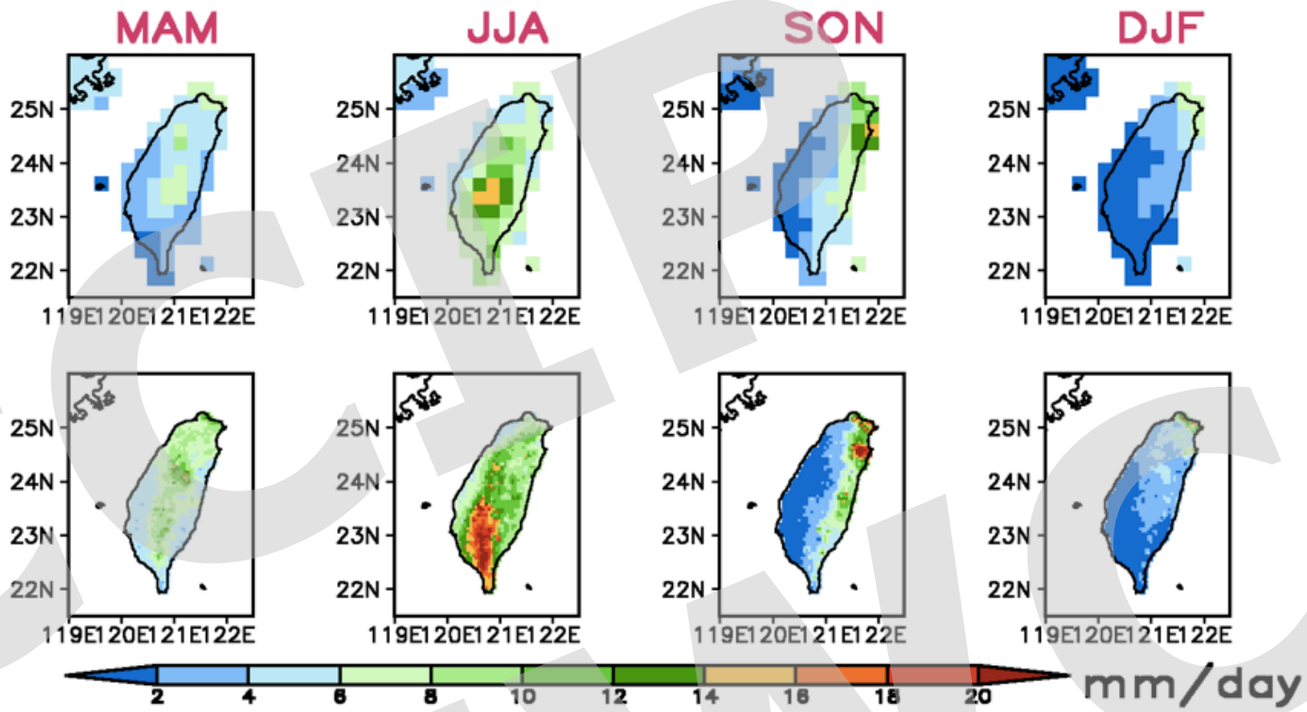
2-stages downscaling



2-stages: (1) GCM ⇒0.25° (2) 0.25°⇒ 5 km

Aphrodite 0.25°

Taiwan gridded 5km



CMIP5 Model Projected Future Change in Precipitation (%) RCP8.5

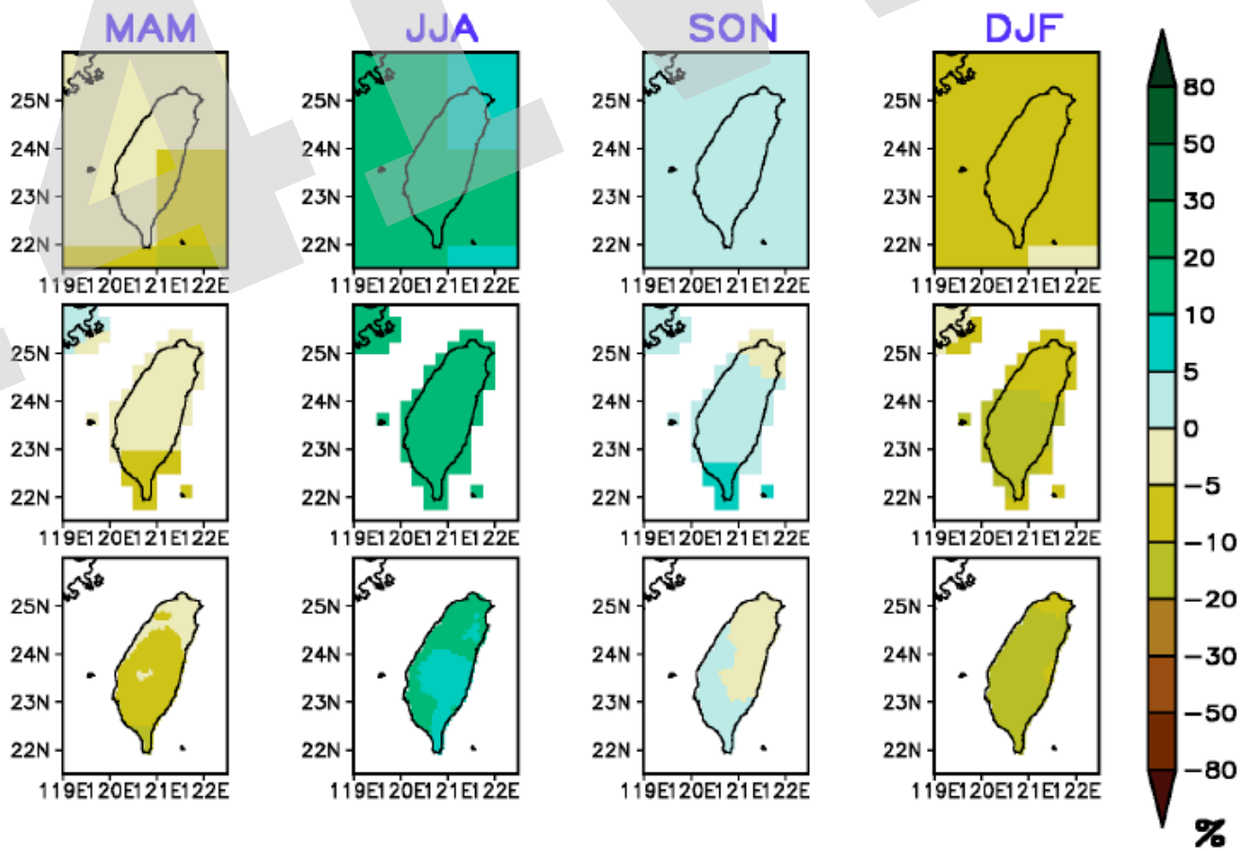
(1)

(2)

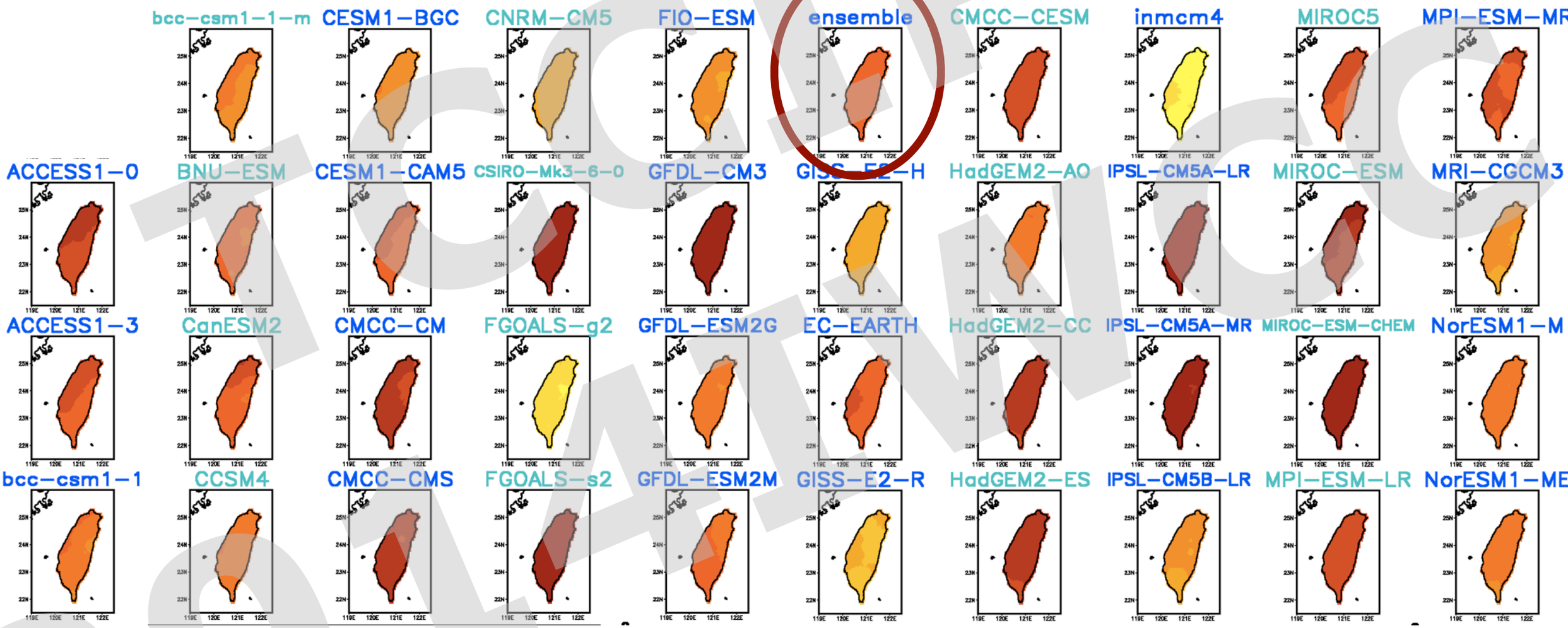
Model Resolution

25 km

5 km

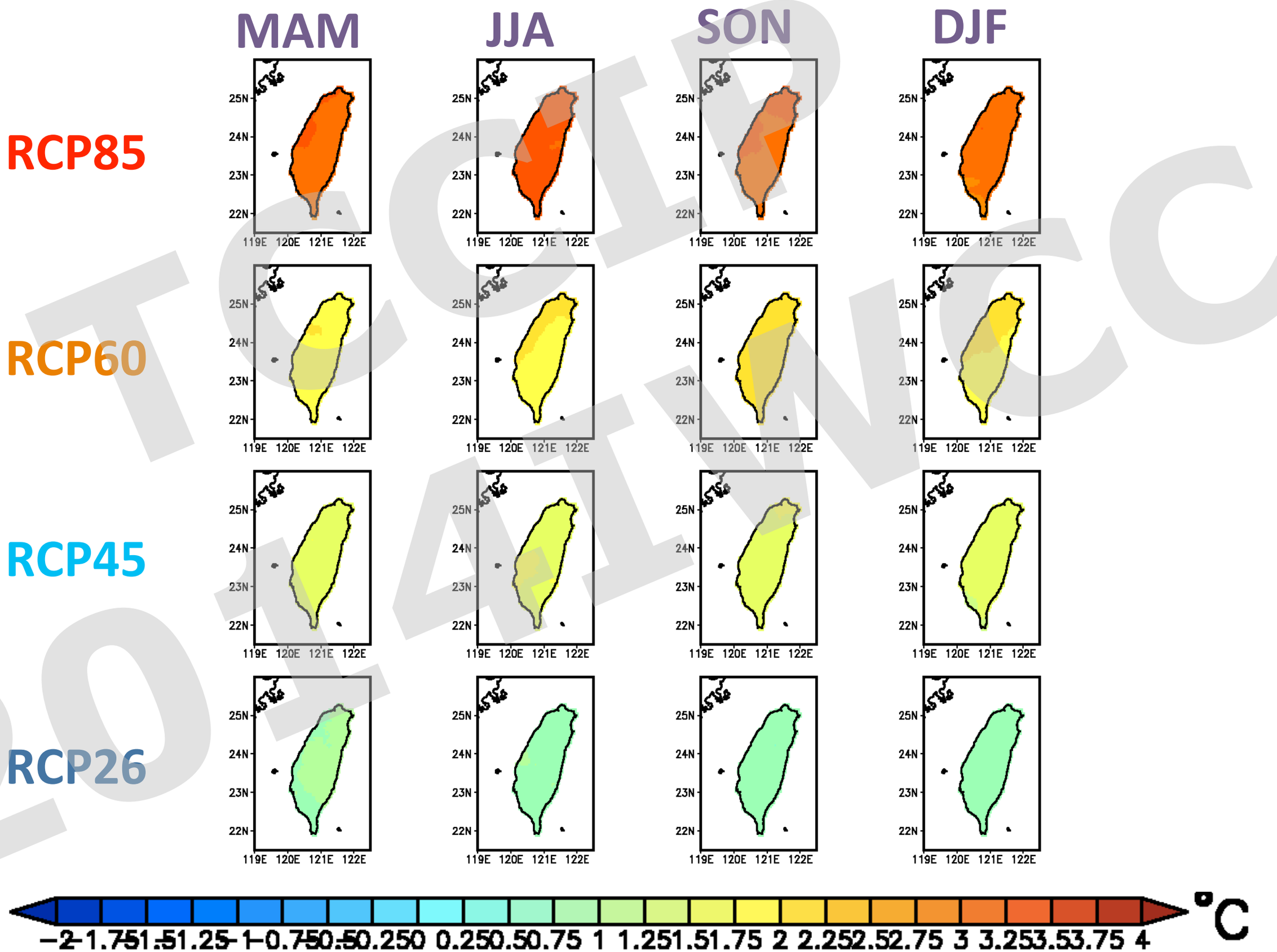


RCP85 2080-99 JJA Surface Air Temperature Change



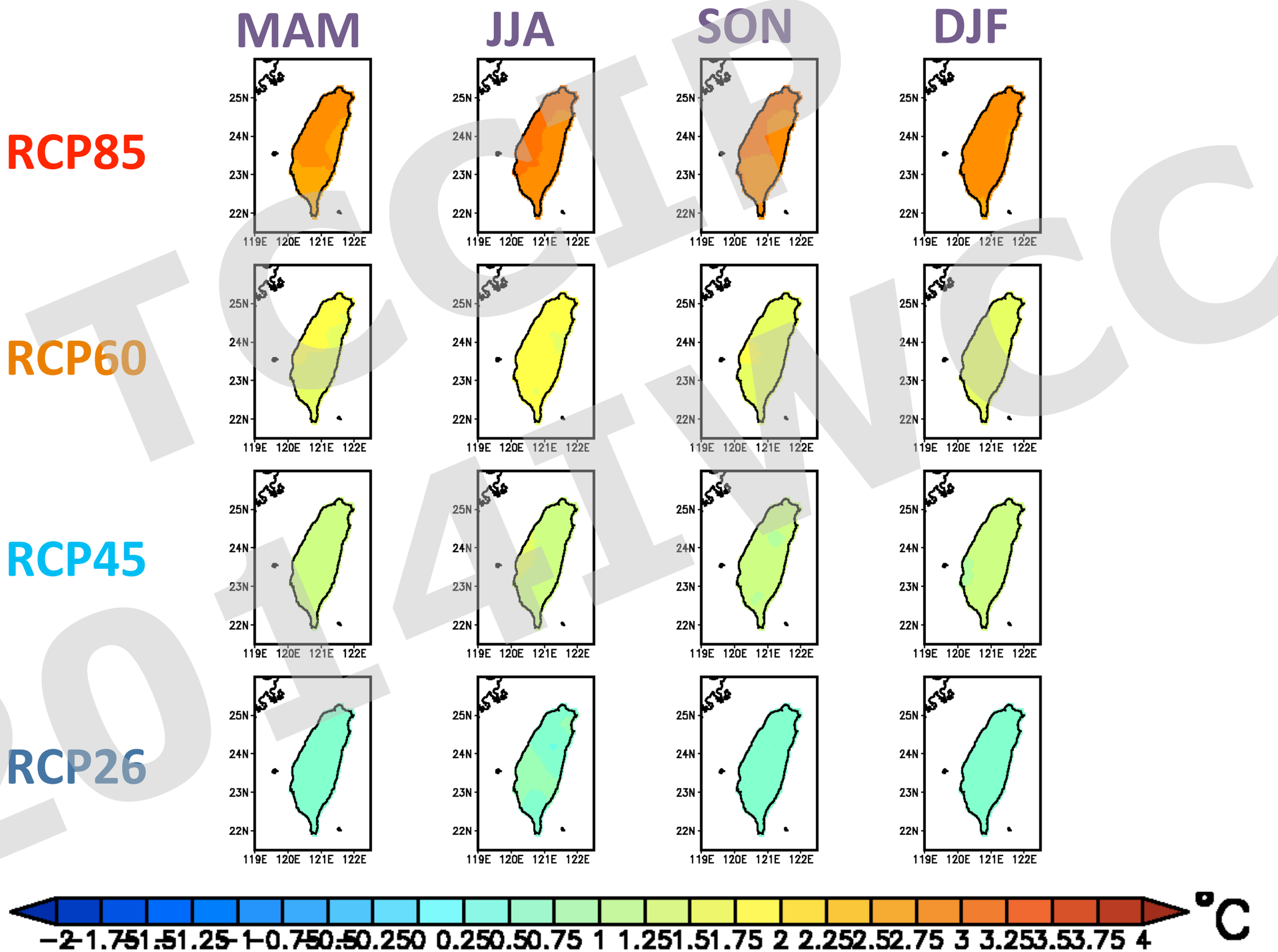
CMIP5 2080-2099

Projected Temperature Change (Median)



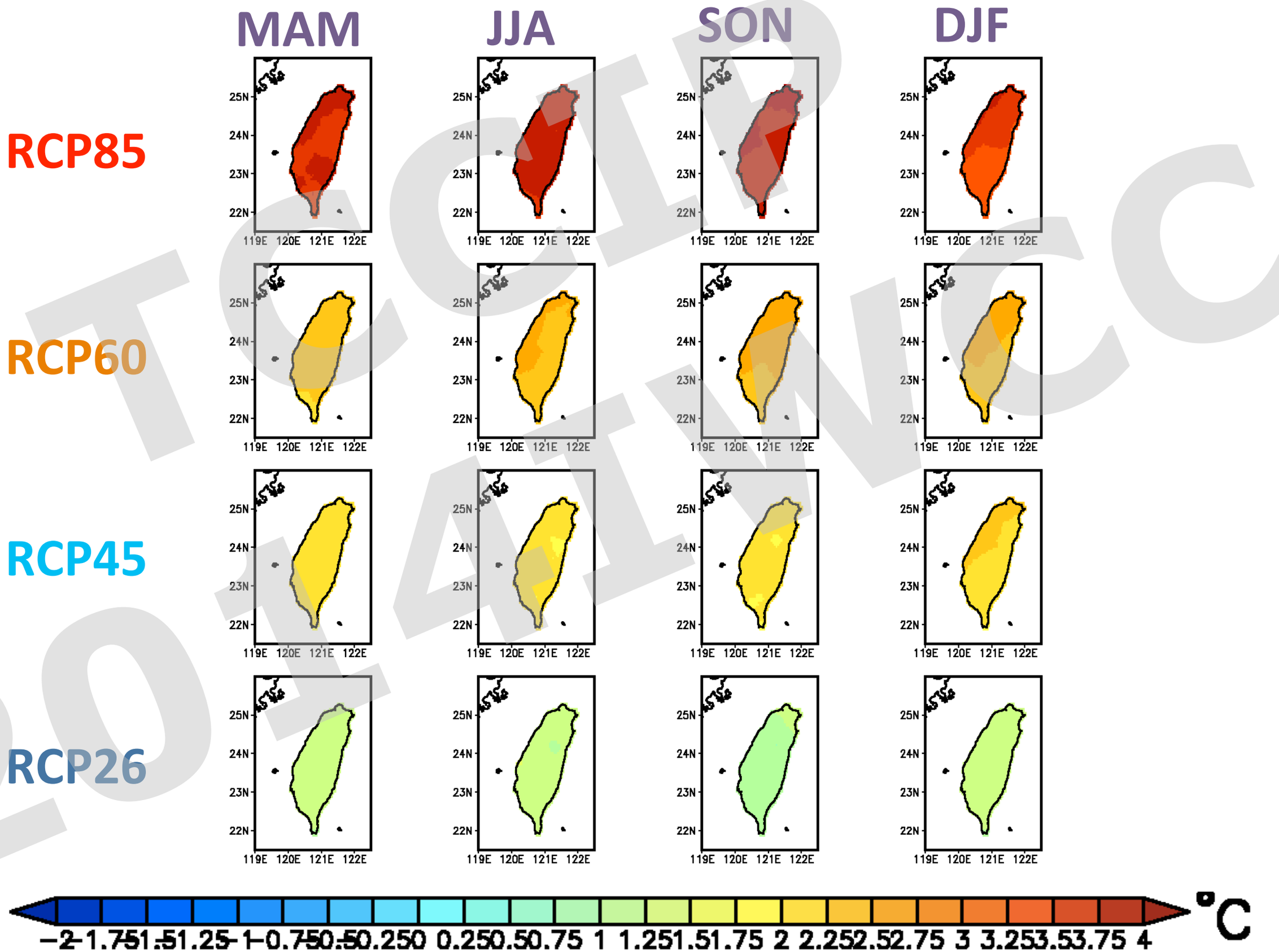
CMIP5 2080-2099

Projected Temperature Change (25th Percentile)



CMIP5 2080-2099

Projected Temperature Change (75th Percentile)



CMIP5 2080-2099

Projected Precipitation Change (Median)

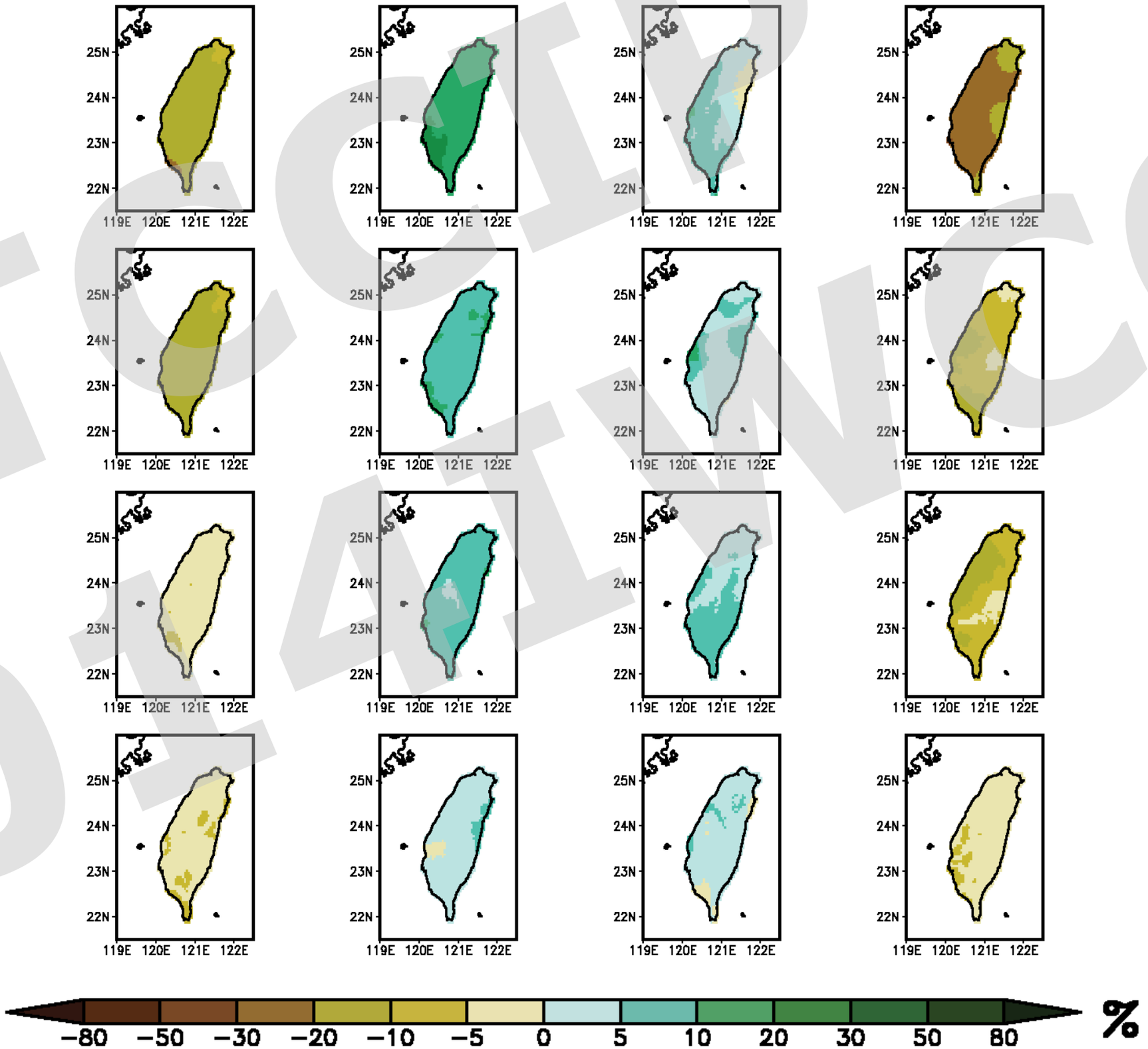
MAM JJA SON DJF

RCP85

RCP60

RCP45

RCP26



CMIP5 2080-2099

Projected Precipitation Change (25th Percentile)

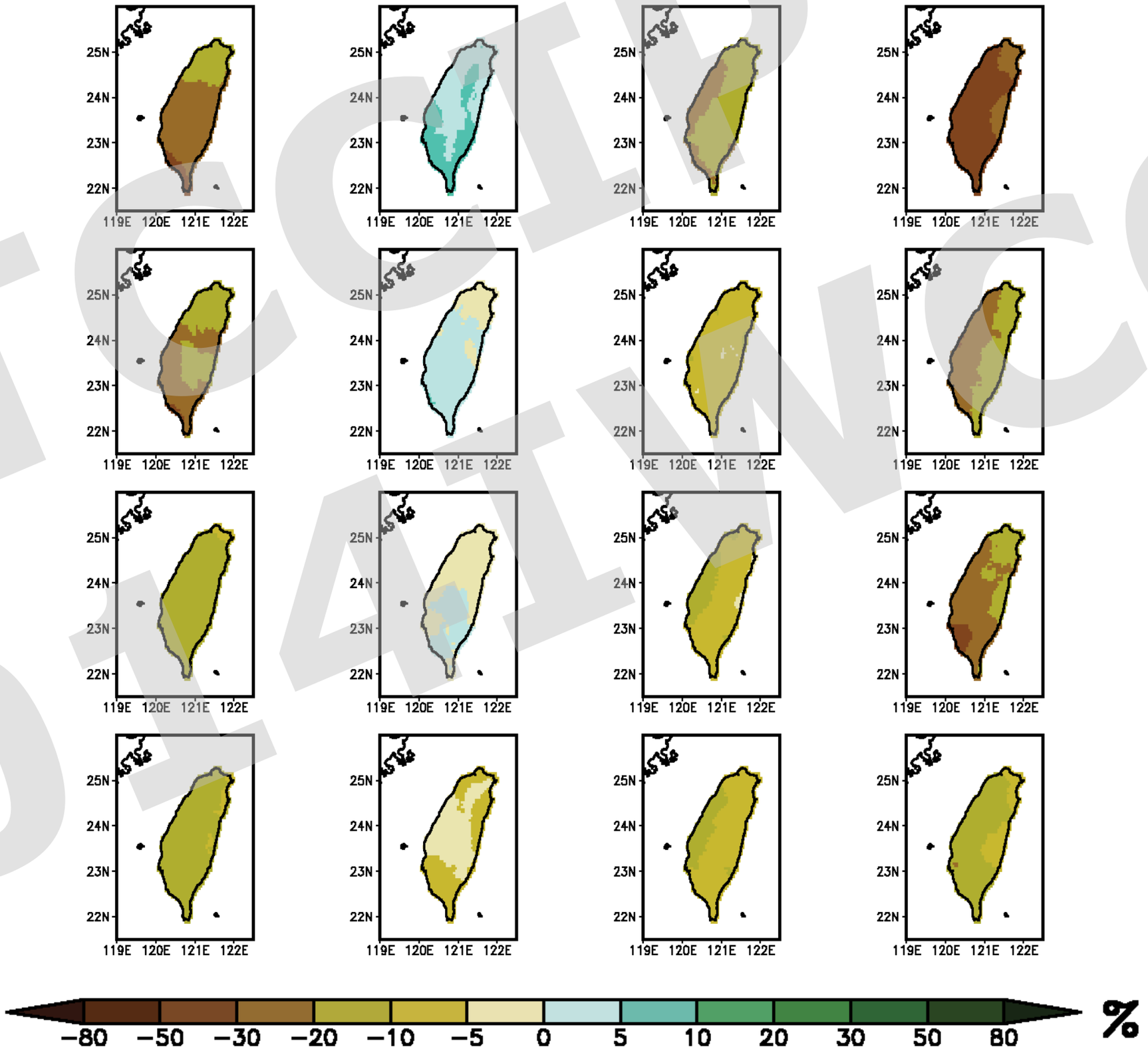
MAM JJA SON DJF

RCP85

RCP60

RCP45

RCP26



CMIP5 2080-2099

Projected Precipitation Change (75th Percentile)

MAM JJA SON DJF

RCP85

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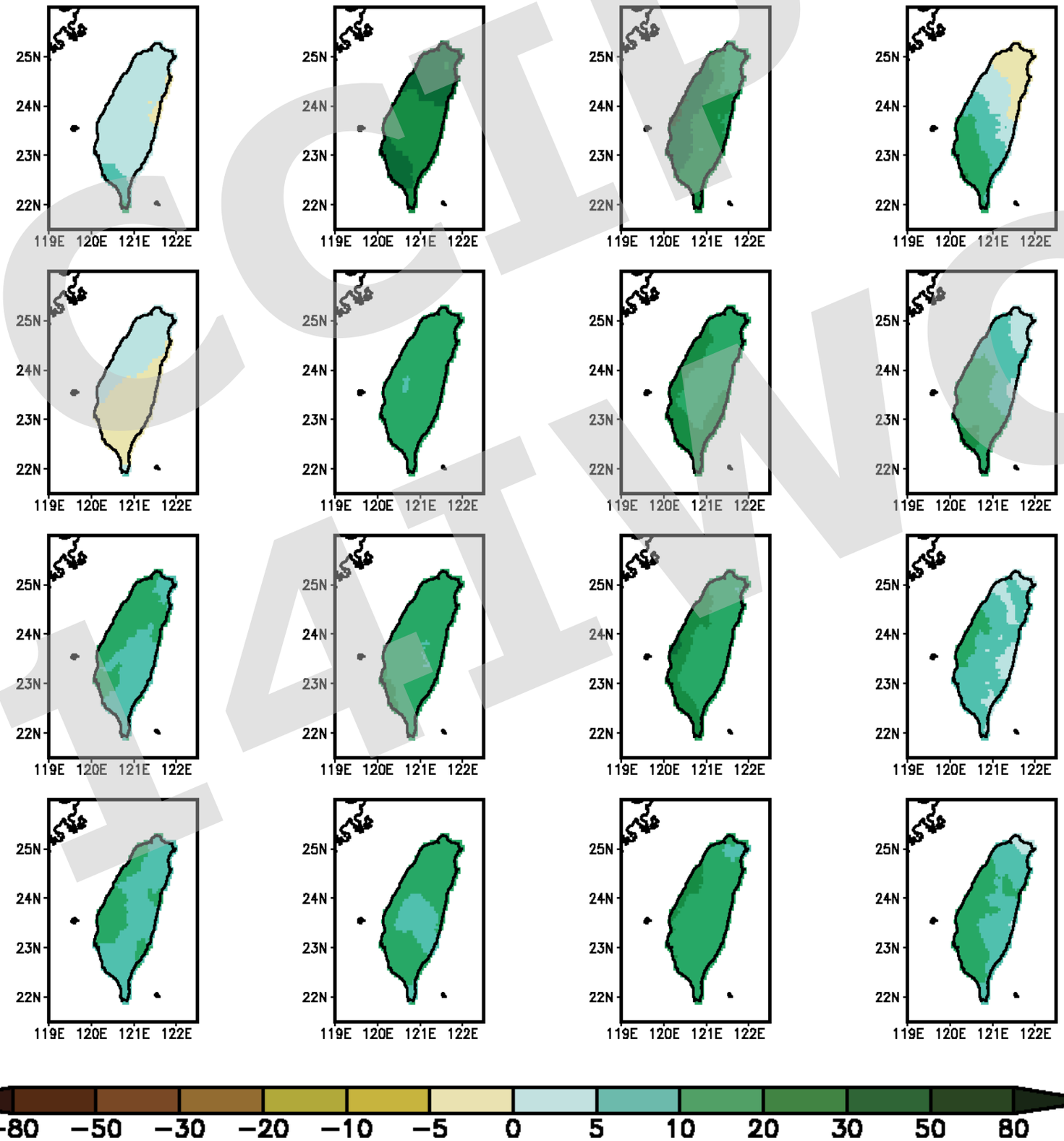
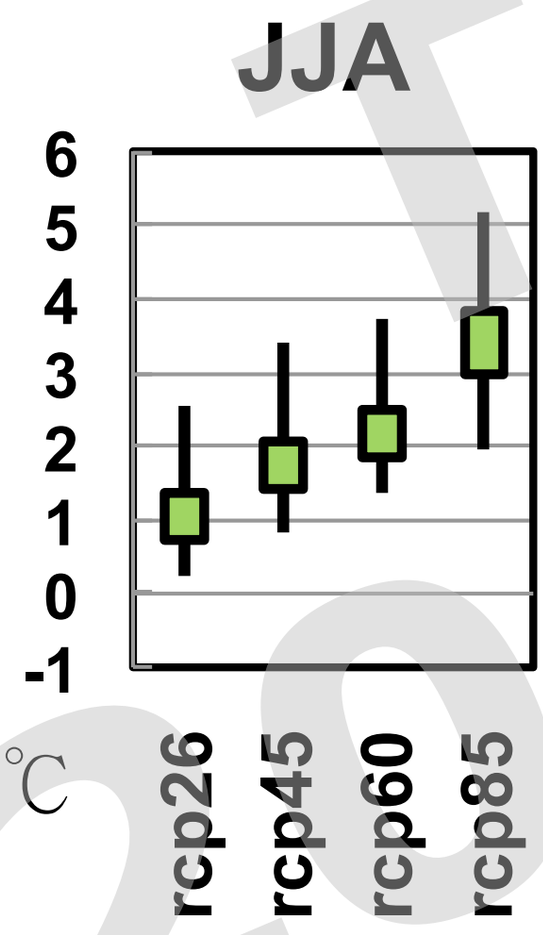
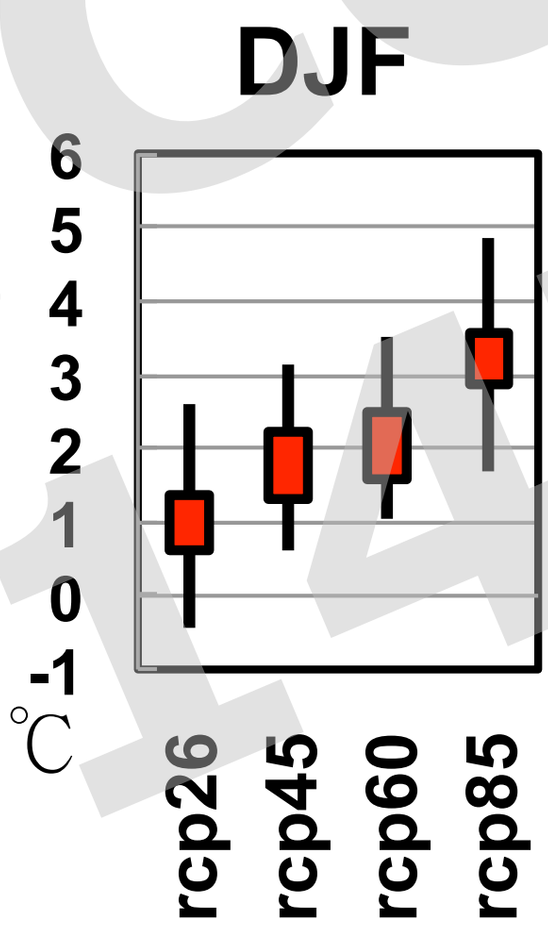


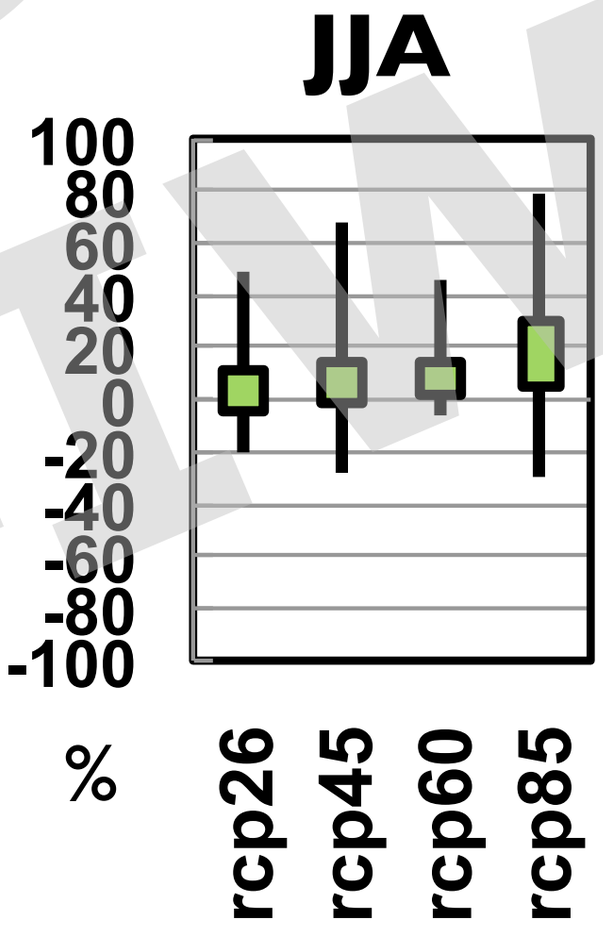
Box-Whisker Plots of CMIP5 Model Projected Taiwan Mean Future (2080-2099) Climate Change with RCP8.5 scenario

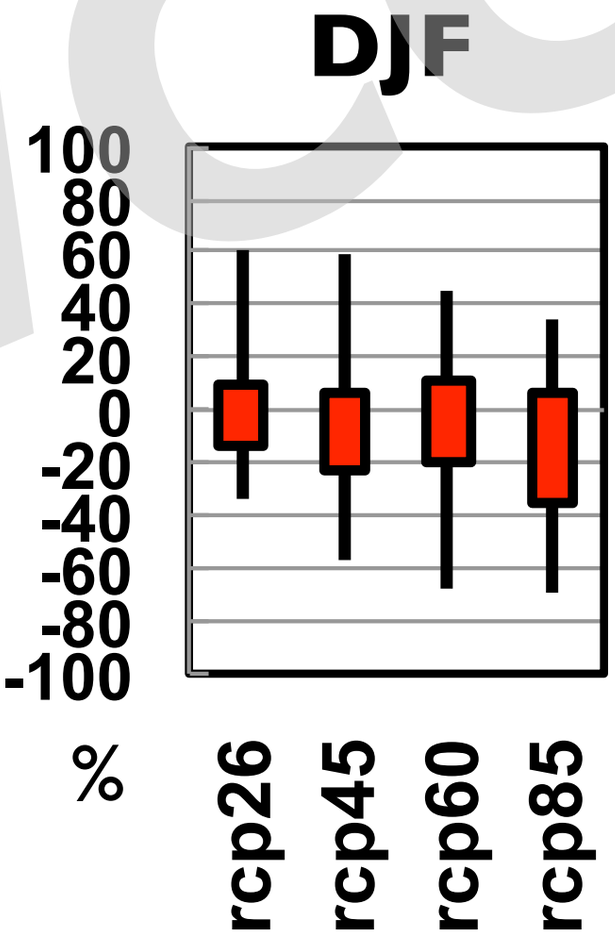
Taiwan Mean Temperature Change





Taiwan Mean Precipitation Change





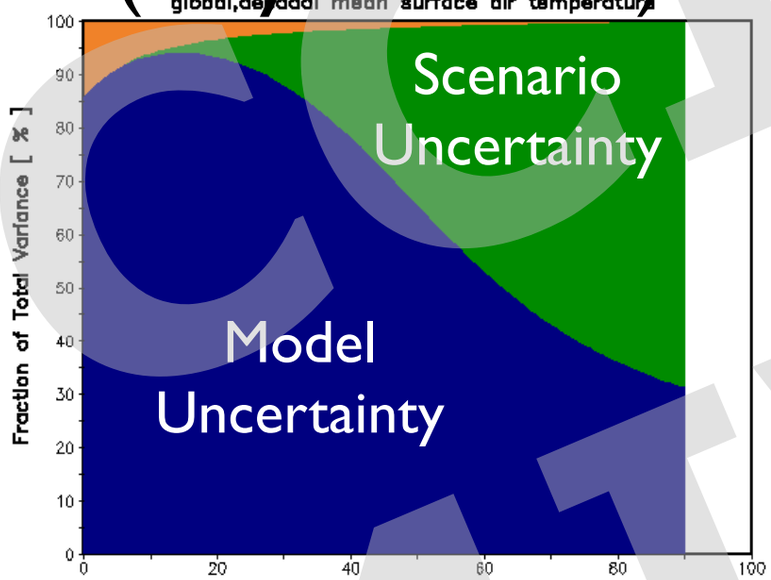
Uncertainties Assessment (Hawkin and Sutton, 2009)

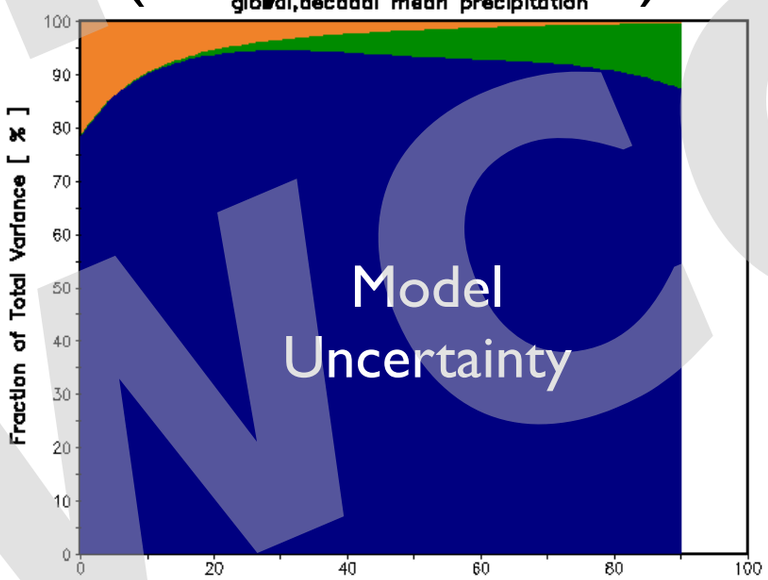
Fraction of Total Variance Plot (Scenario, Model, Internal Variability)

Surface Air Temperature (20 year mean)

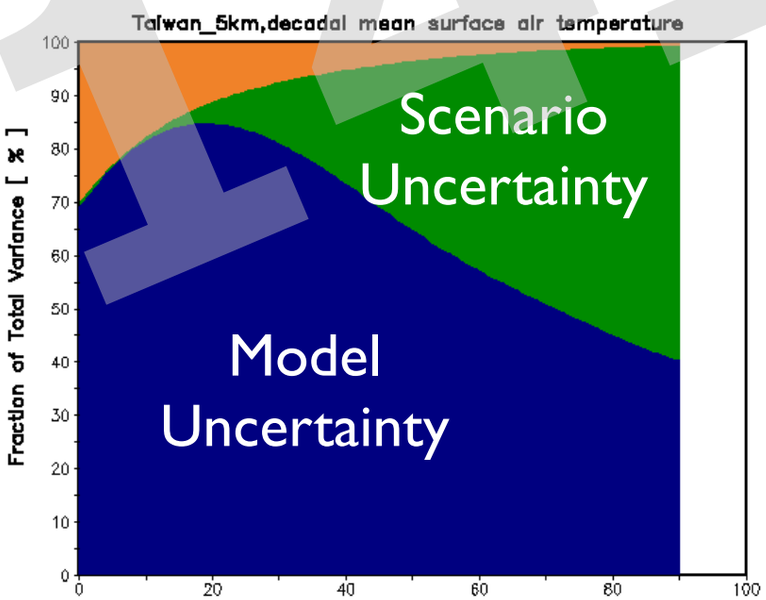
Precipitation (20 year mean)

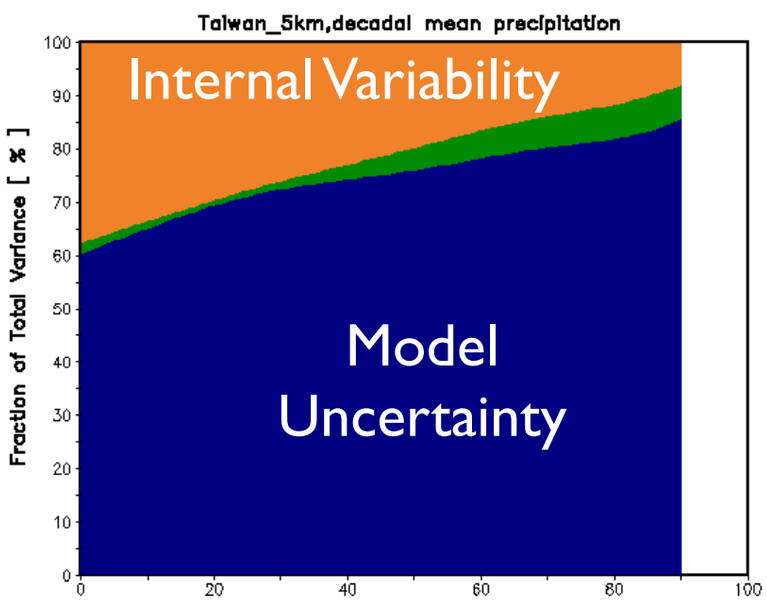
Global





Taiwan





Summary and Concluding Remarks

- 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.
- For Taiwan region, scenario uncertainty become more dominate for future warming at the end of century, but only very limited contribution to the future precipitation change. Model uncertainty is the main reason for the range of projected future rainfall change. Internal variability can have sizable influence on regional to local climate changes.

- Internal variability

$$V = \sum_m W_m \, var_{s,t}(\varepsilon_{m,s,t})$$

- Model uncertainty

$$M(t) = \frac{1}{N_s} \sum_s var_m{}^w (x_{m,s,t})$$

- Scenario uncertainty

$$s(t) = var_s\left(\sum_m W_m \, x_{m,s,t}\right)$$

- Mean change

$$G(t) = \frac{1}{N_s} \sum_{m,s} W_m x_{m,s,t}.$$

- total variance

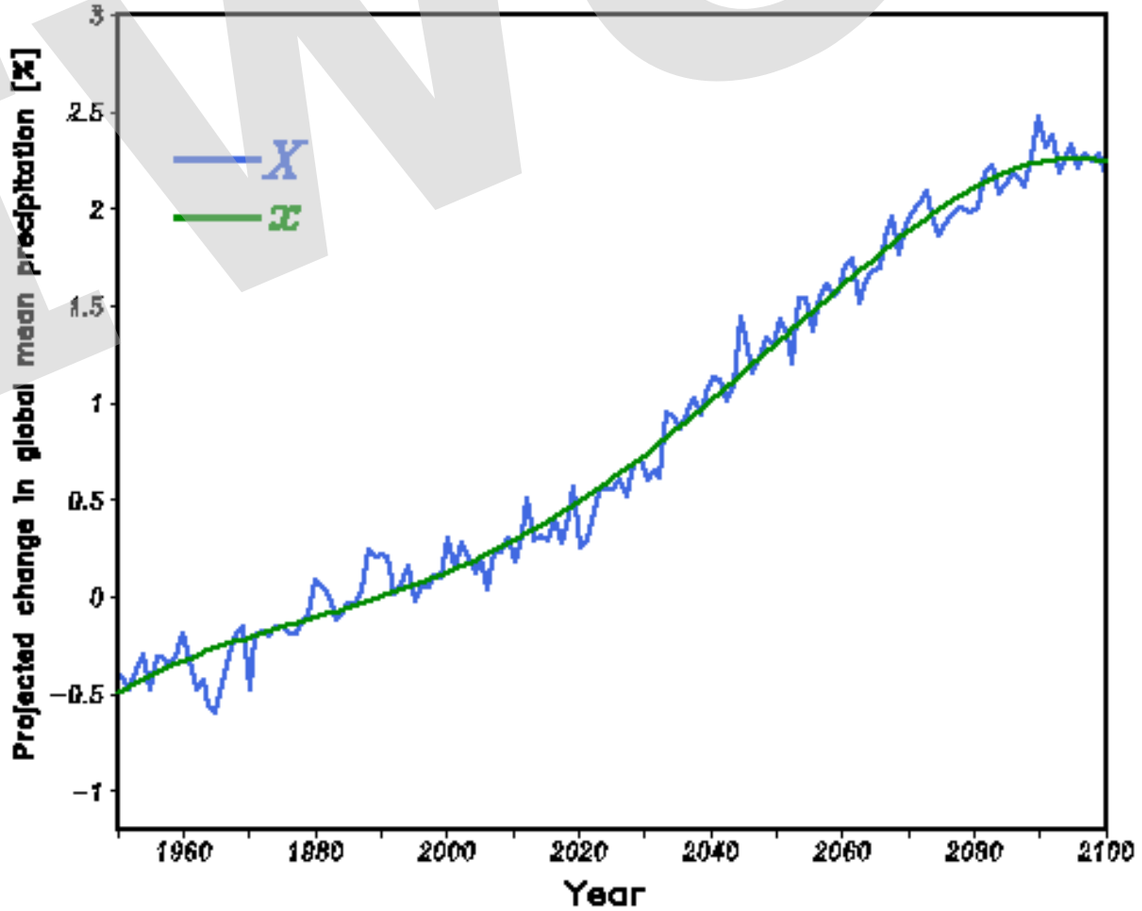
$$T(t) = V + S(t) + M(t)$$

- fractional uncertainty (90% confidence level)

$$F(t) = \frac{1.65\sqrt{T(t)}}{G(t)}.$$

- Each individual prediction was fit, using ordinary least squares, with a fourth-order polynomial over the years 1950–2099.

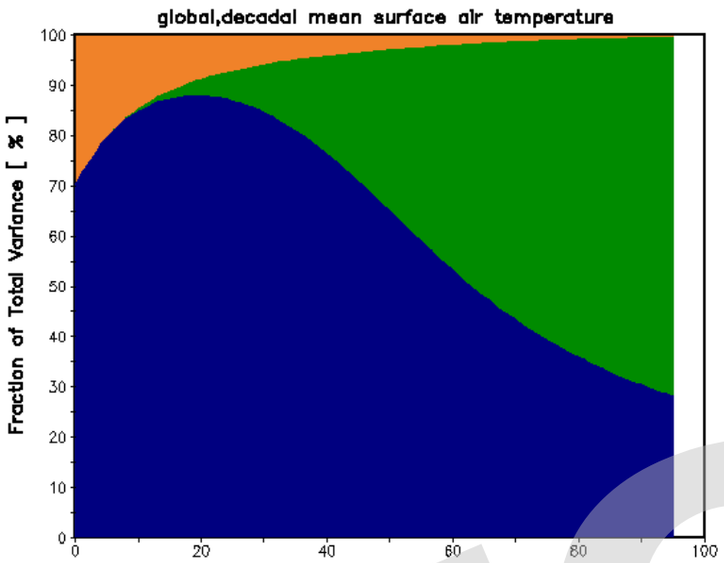
- $X_{m,s,t} = x_{m,s,t} + \varepsilon_{m,s,t}$
  - *m = model*
  - *s* = scenario
  - *t = year*
  - ε = internal variability

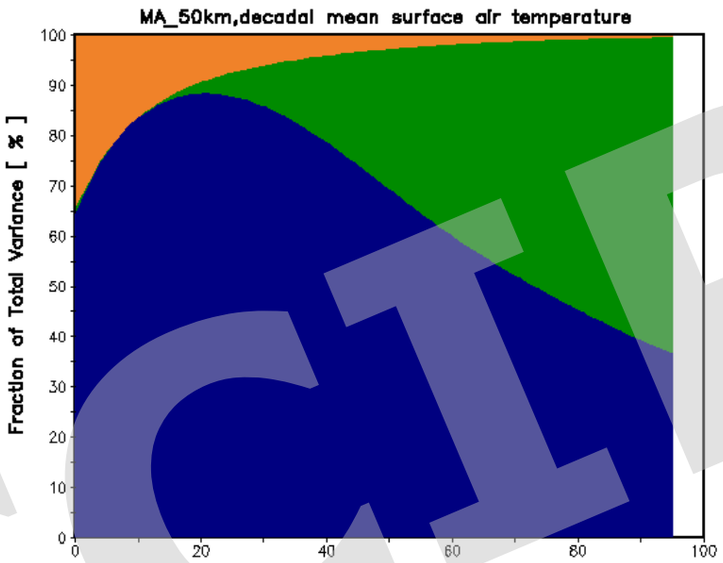


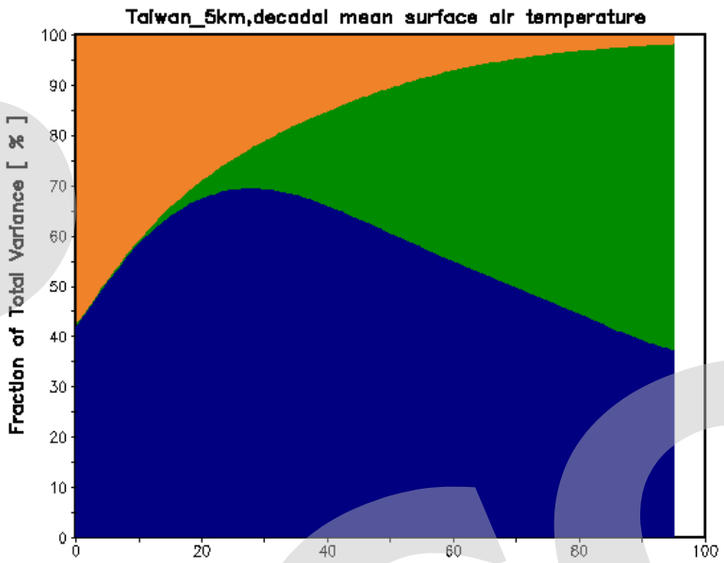
Global

MA_50km

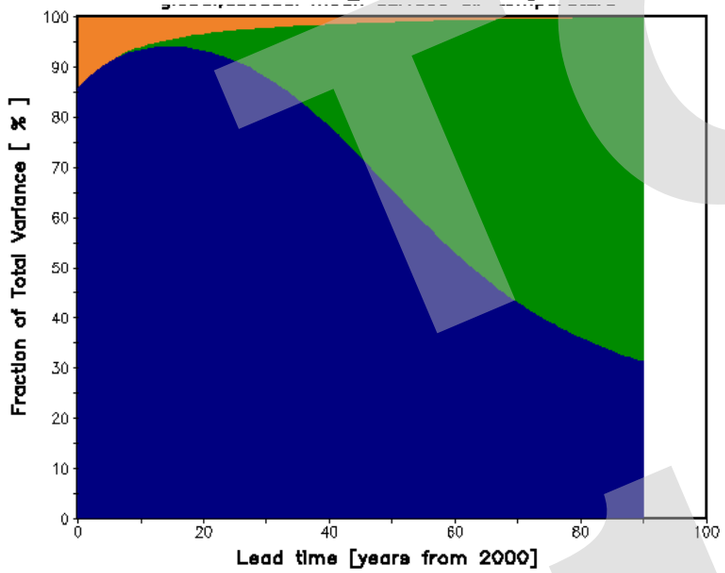
Taiwan_5km

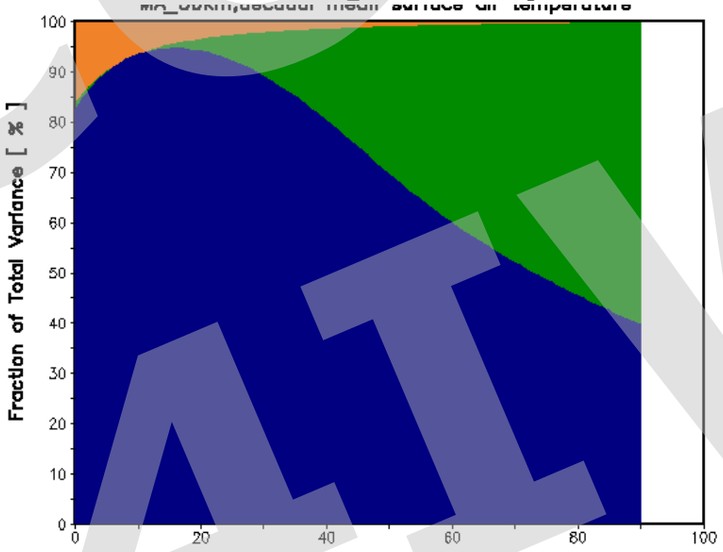


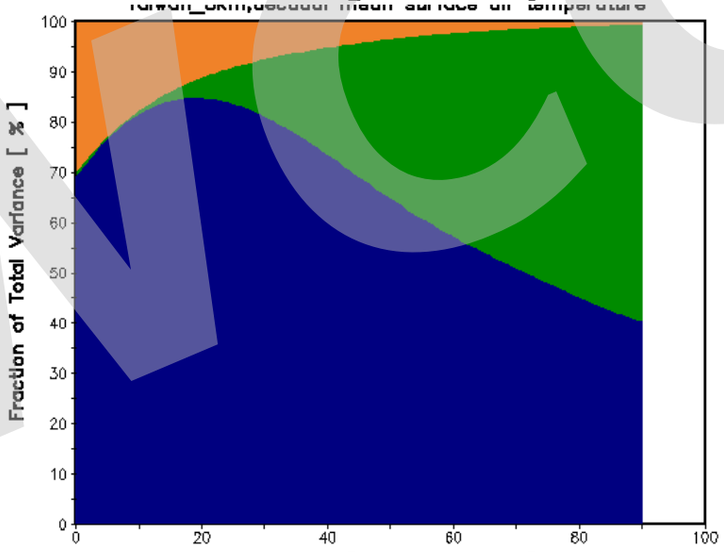




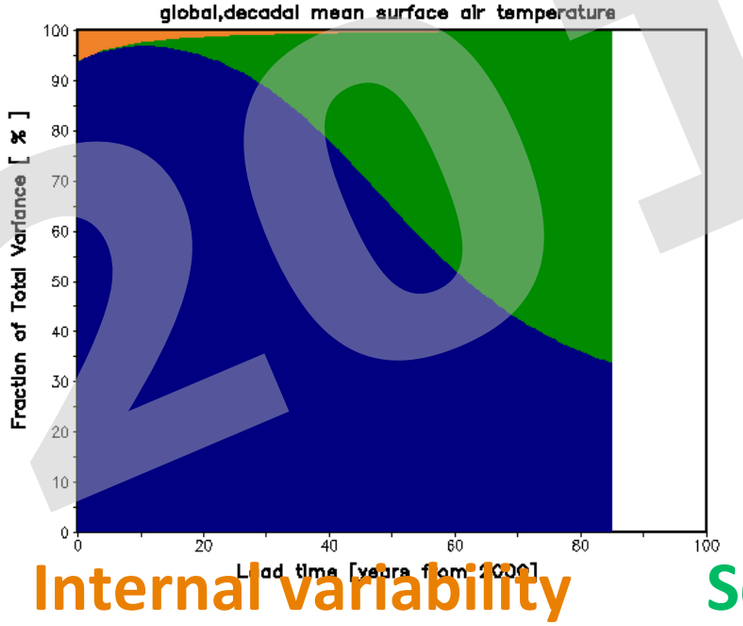
10 year runmean

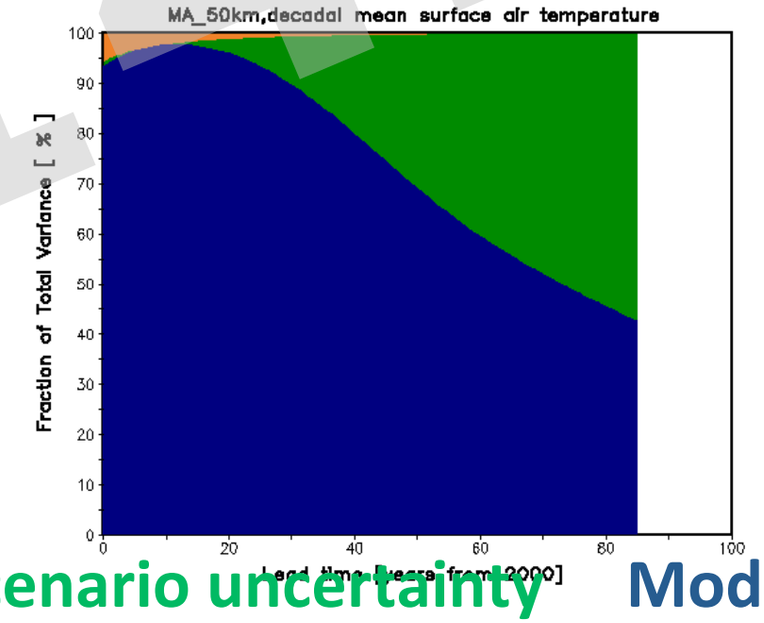


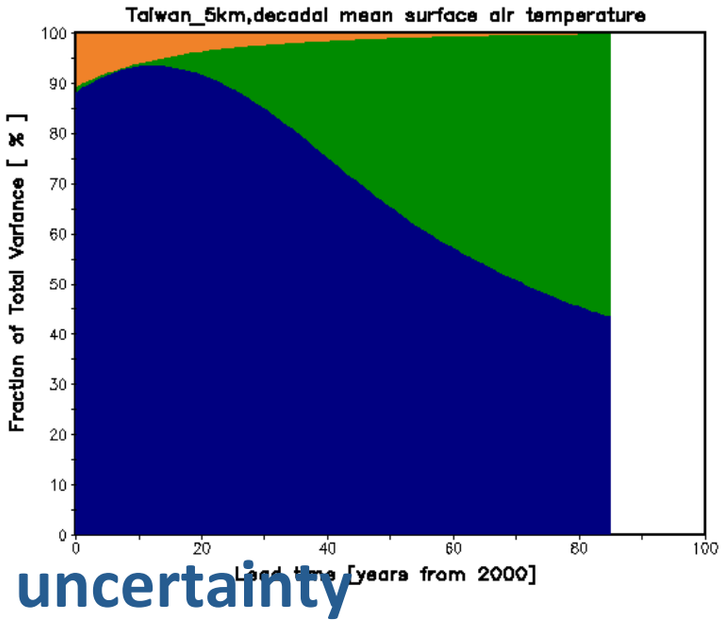




20 year runmean







30 year runmean

Internal variability

Scenario uncertainty

Model uncertainty