Statistical Downscaling over Taiwan:

Current Daily Data Products and Future Developments

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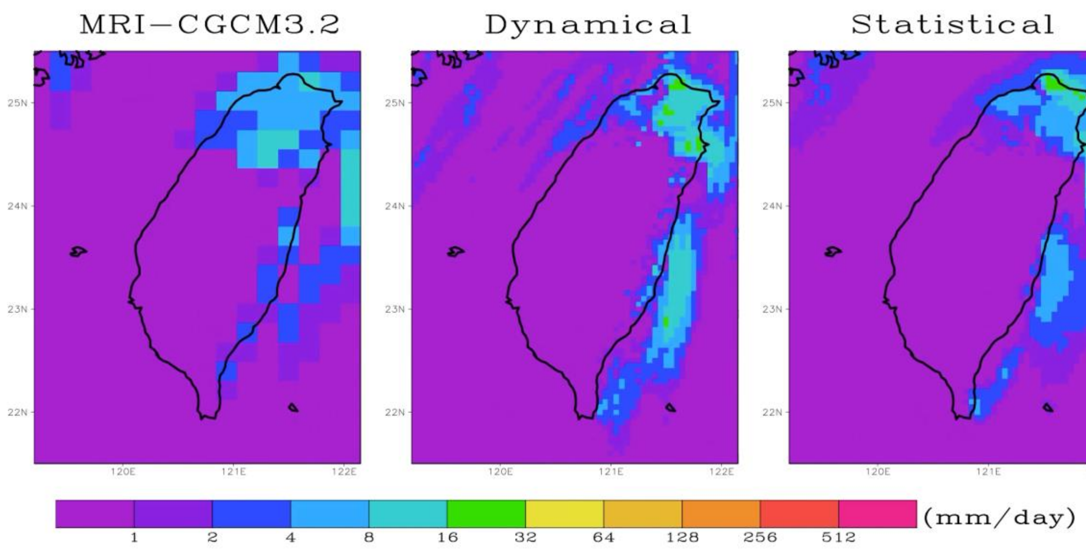


Downscaling

Downscaling Objectives:

(1) Bridge/conduit from large to small scales
(2) Correct systematic model biases

[too cold/warm, wet/dry, etc.]

Statistical Downscaling Advantage:

(1) Cheaper to generate

(2) Easy to test different algorithms

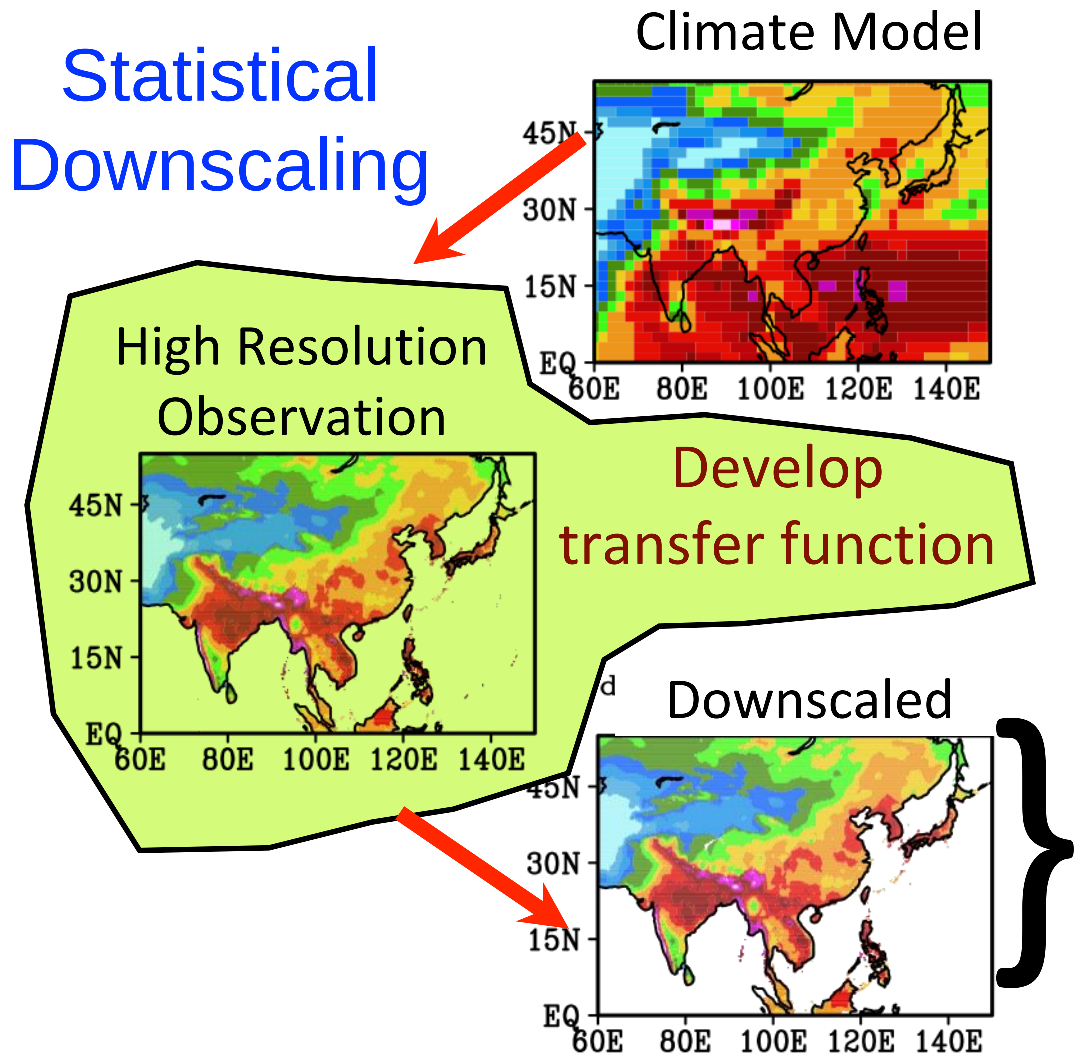
[Synchronous, Asynchronous, Map-typing, etc]

Statistical Downscaling Disadvantage:

(1) No clear theoretical or empirical choice for the best

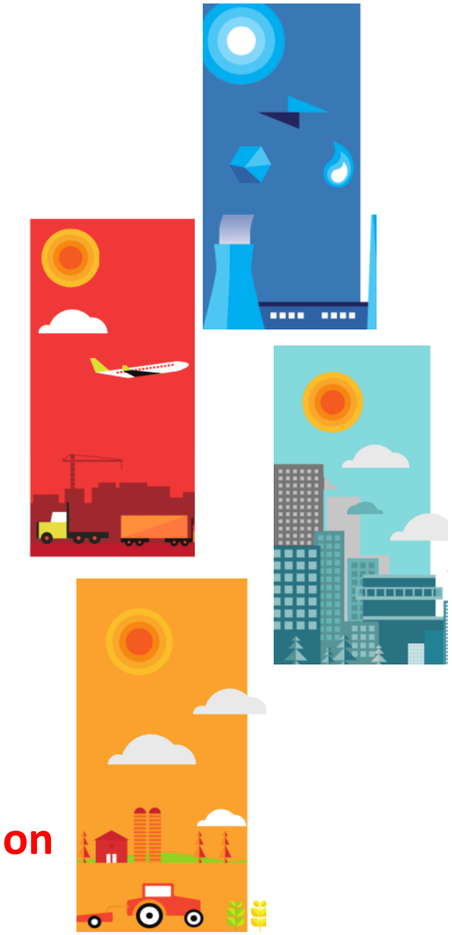
(2) Stationarity assumption

Statistical Downscaling



IMPACTS

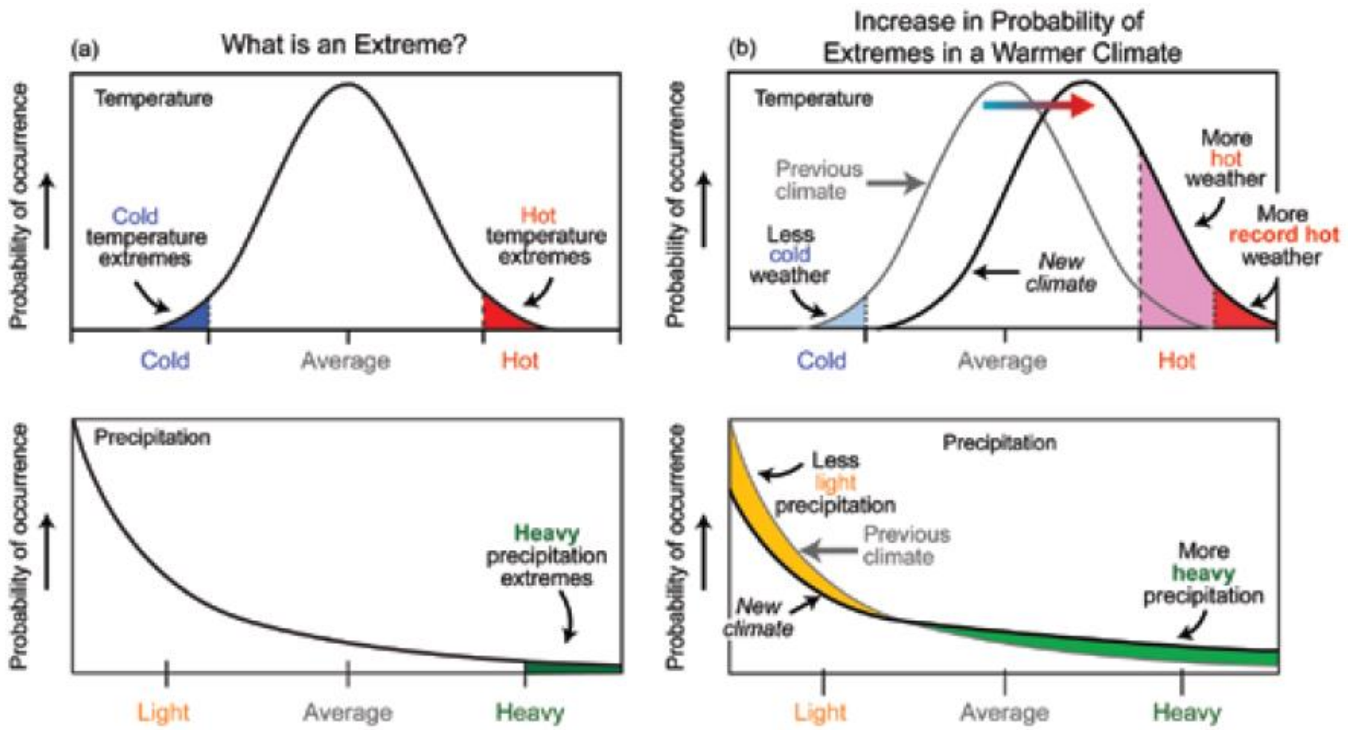
Hydrology
Agriculture
Ecosystems
Energy
Transportation
Health
Air Quality



Statistical Downscaling for Extremes

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

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





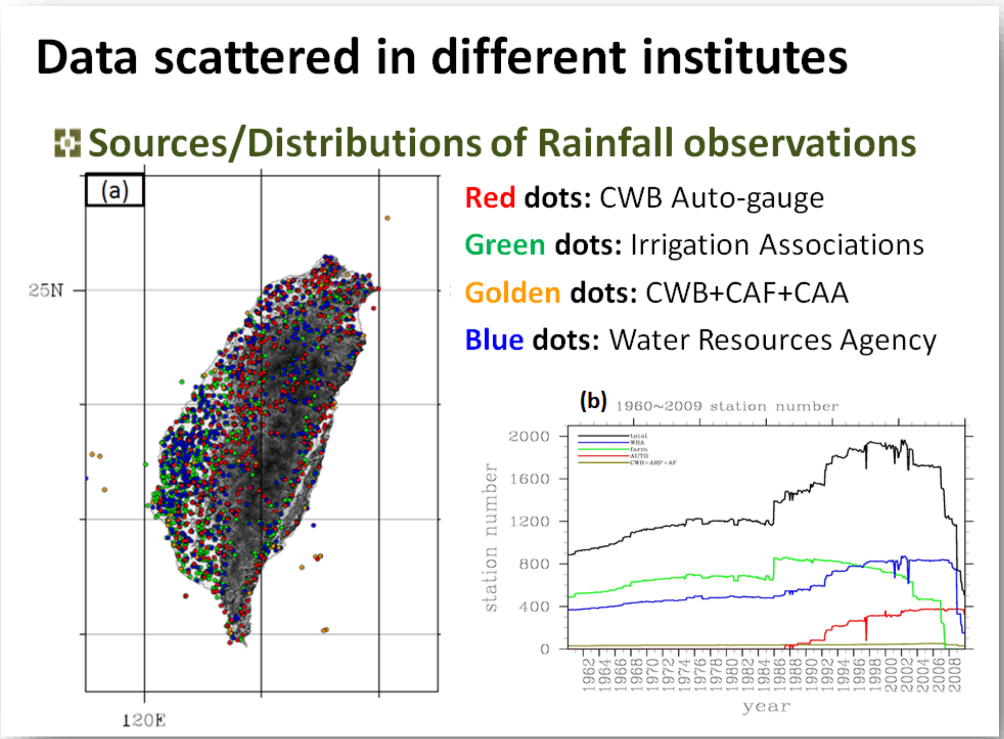


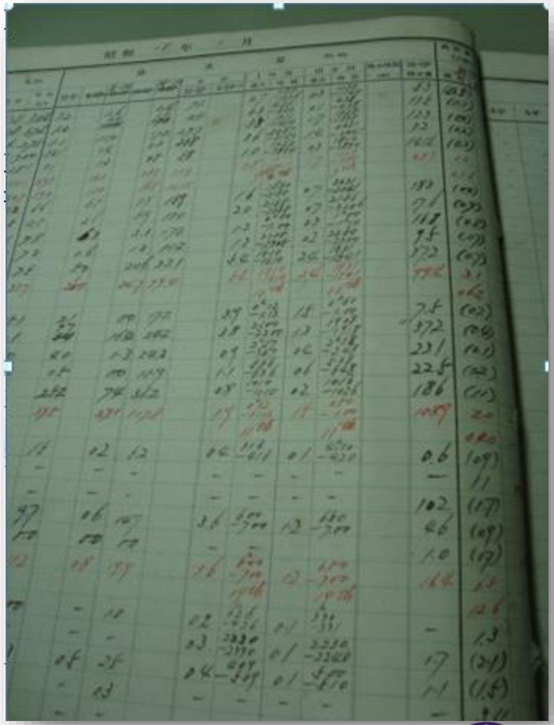




TCCIP Observation Gridded Data

- Integrate data of different institutes (CWB, WRA, IA, CAF, CAA…more than 1400 stations).
- Digitalization and Homogenization for long-term station records (1900-2017)

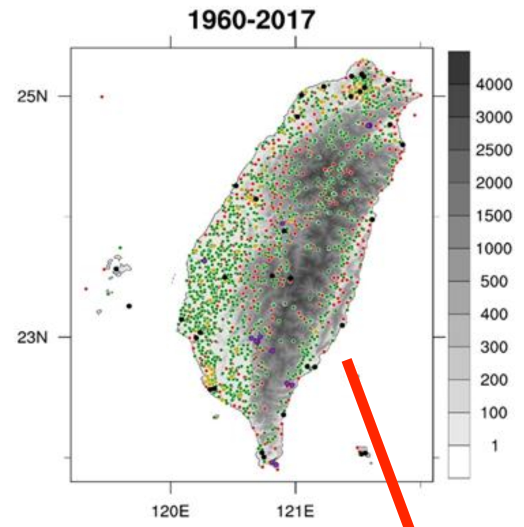




Require long-term high-resolution observations

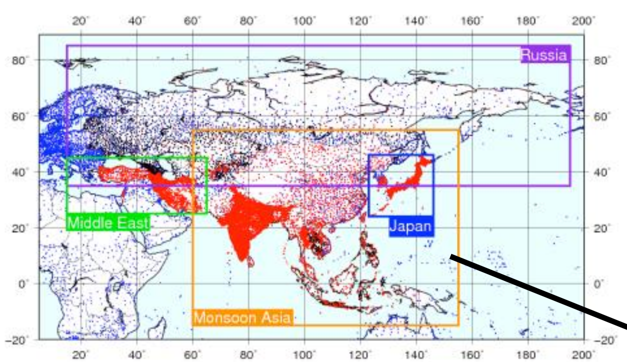
New high-resolution (5km) gridded climate data over Taiwan

TCCIP, Weng and Yang (2015)



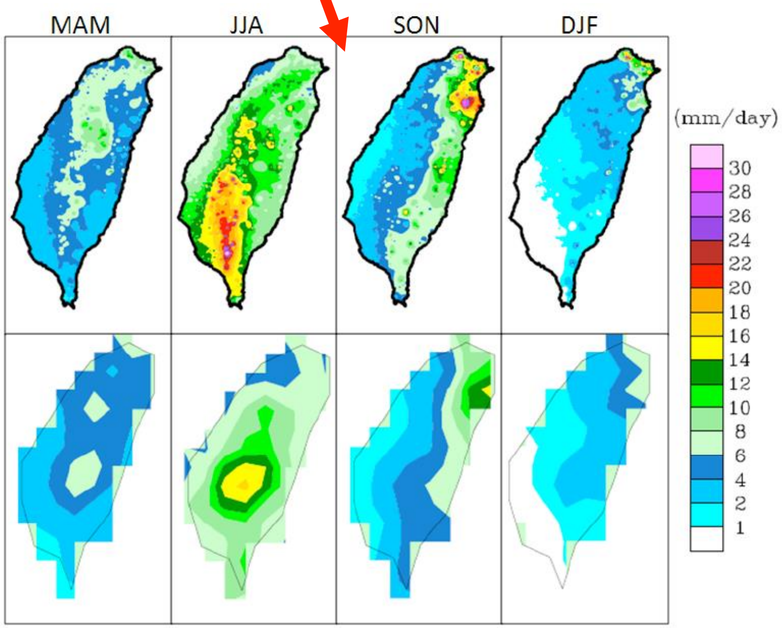
Black: CWB gauge(31)、CAA(10)
Red: CWB Auto-gauge (651)
Yellow: EPA gauge (78)
Green: Agriculture gauge (1337) (WRA、TIRA et. al.)
Purple: TFRI gauge (14)
Total 2121

APHRODITE (0.25°)



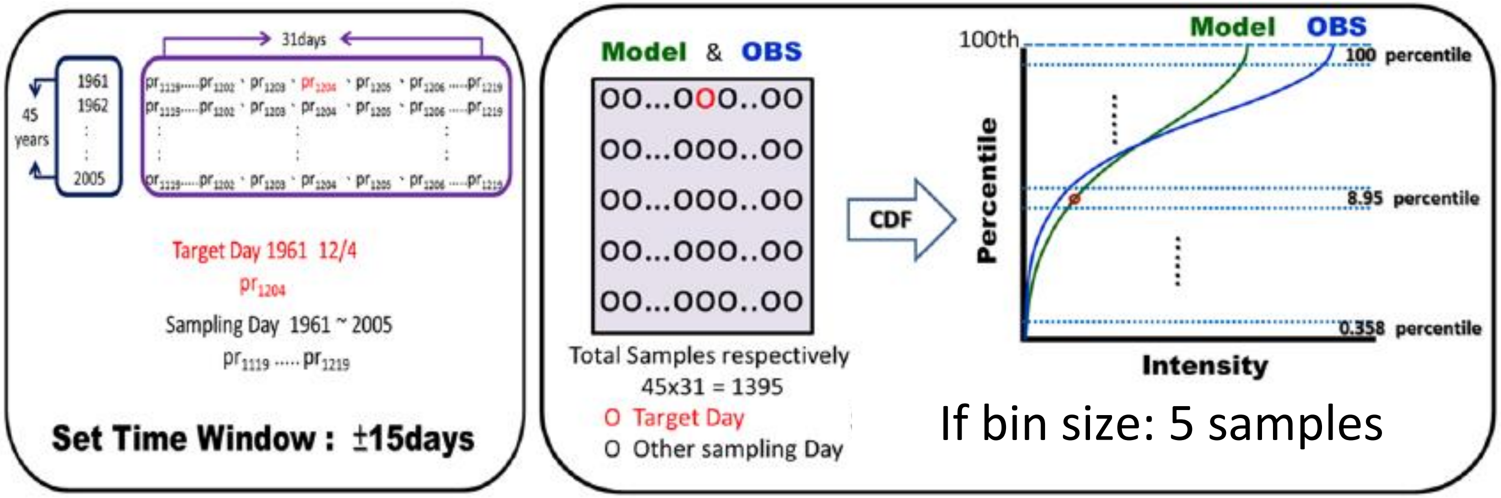
Current version: V1003R1 Download »Readme »Errata

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		



Downscaling Method

Daily Data Bias Correction (Quantile Mapping)



$$OBS_{8.95p} = \sum Pr_{obs121st\text{-}125th} / 5$$

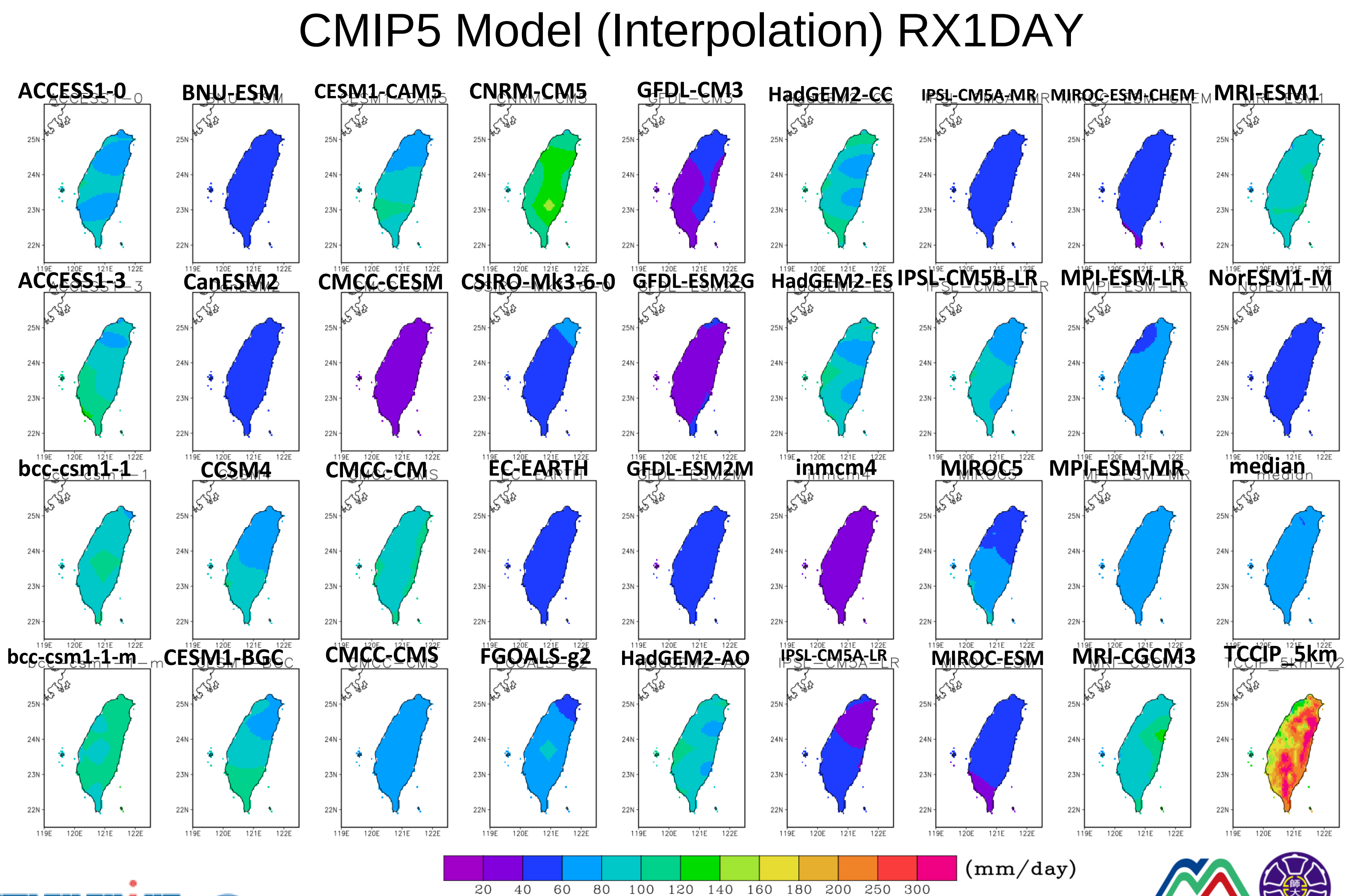
$$Model_{8.95p} = \sum Pr_{model121st\text{-}125th} / 5$$

Target Day 1961 12/4 Model Bias Correction

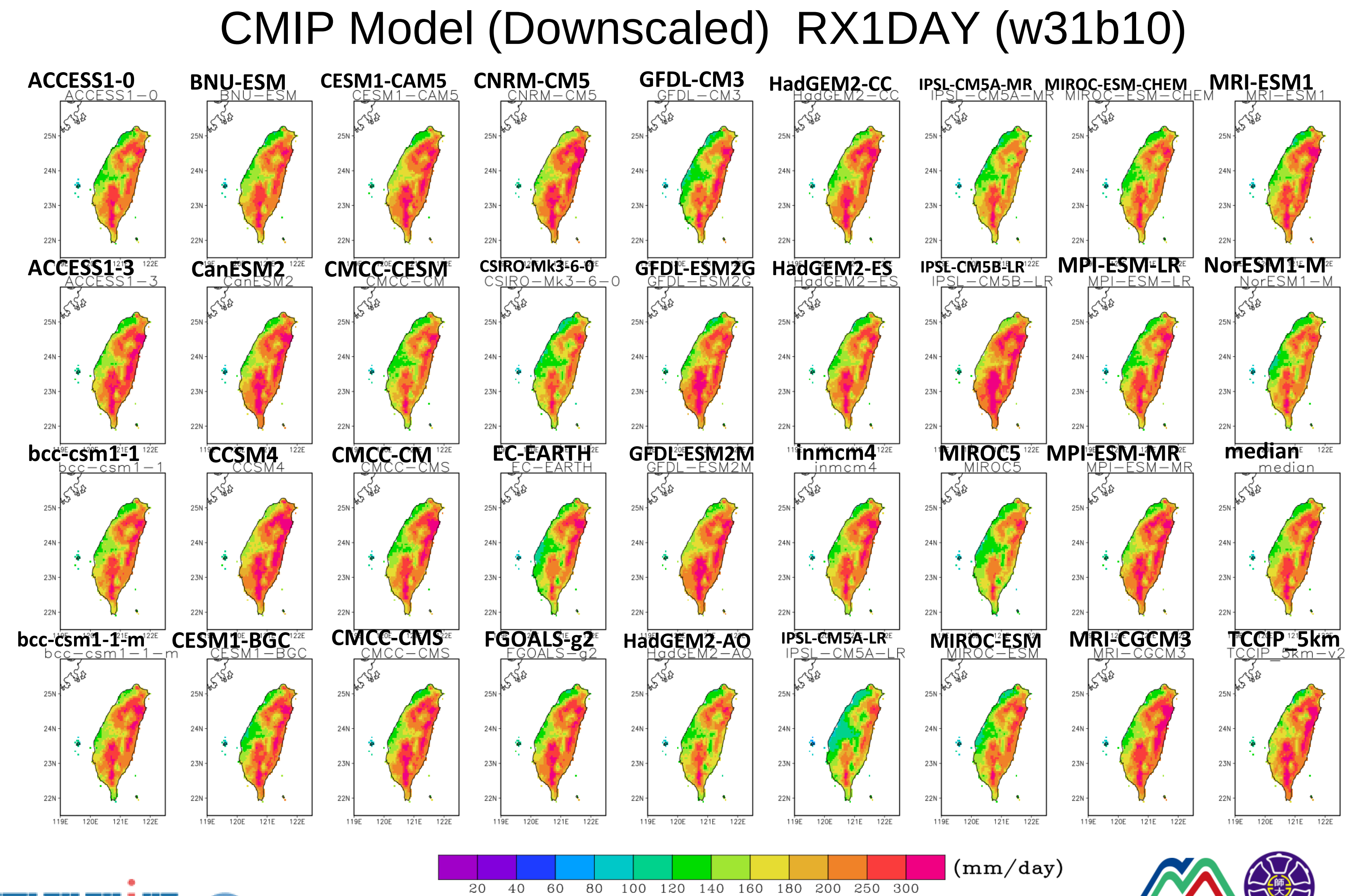
$$Model\_BCpr_{1204} = (Modelpr_{1204} \times OBS_{8.95p} / Model_{8.95p})$$

※ $$Model\_BCT_{1204} = (ModelT_{1204} - Model_{8.95p} + OBS_{8.95p})$$

Rx1day from CMIP5 output interpolated

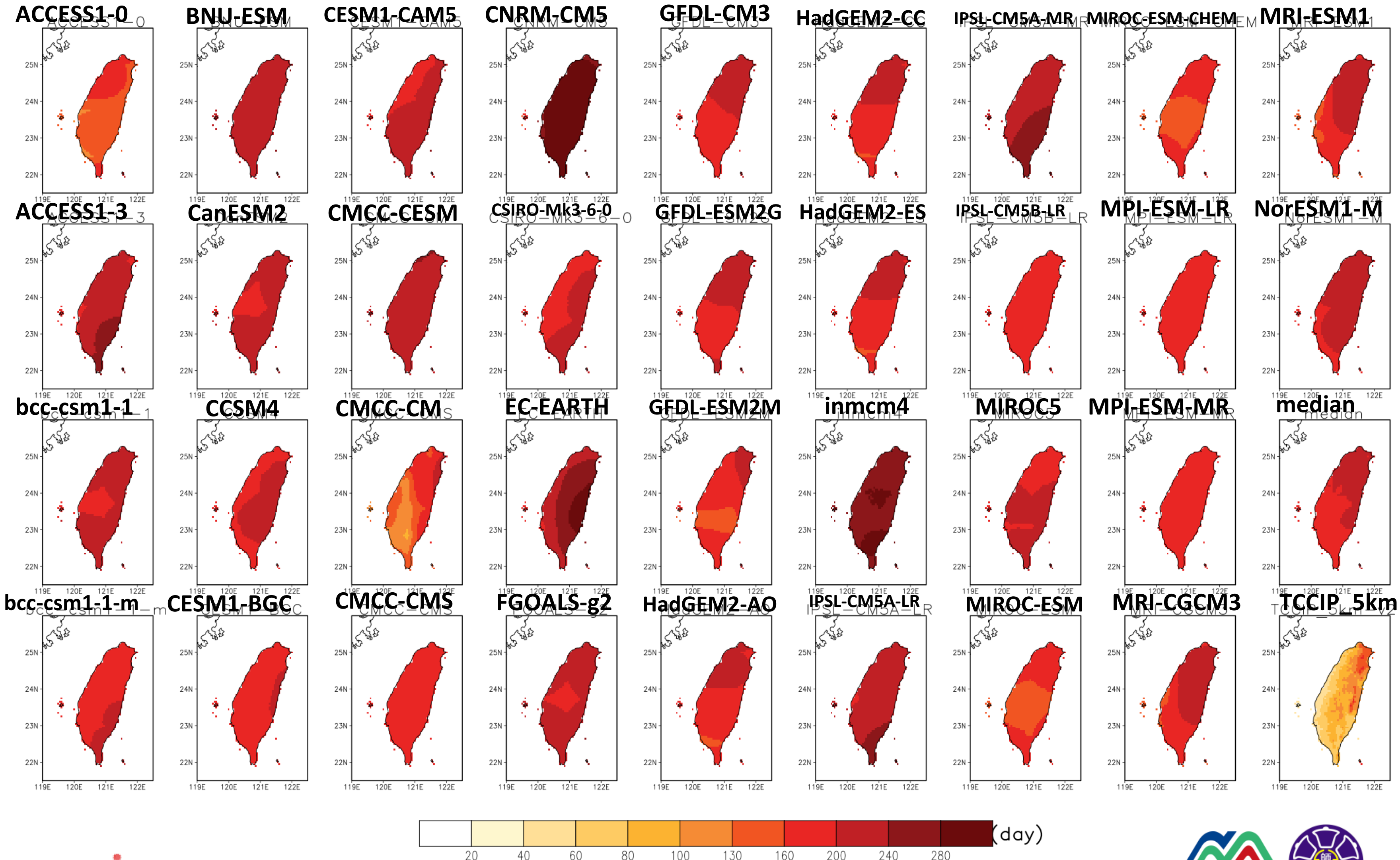


Rx1day from downscaled CMIP5



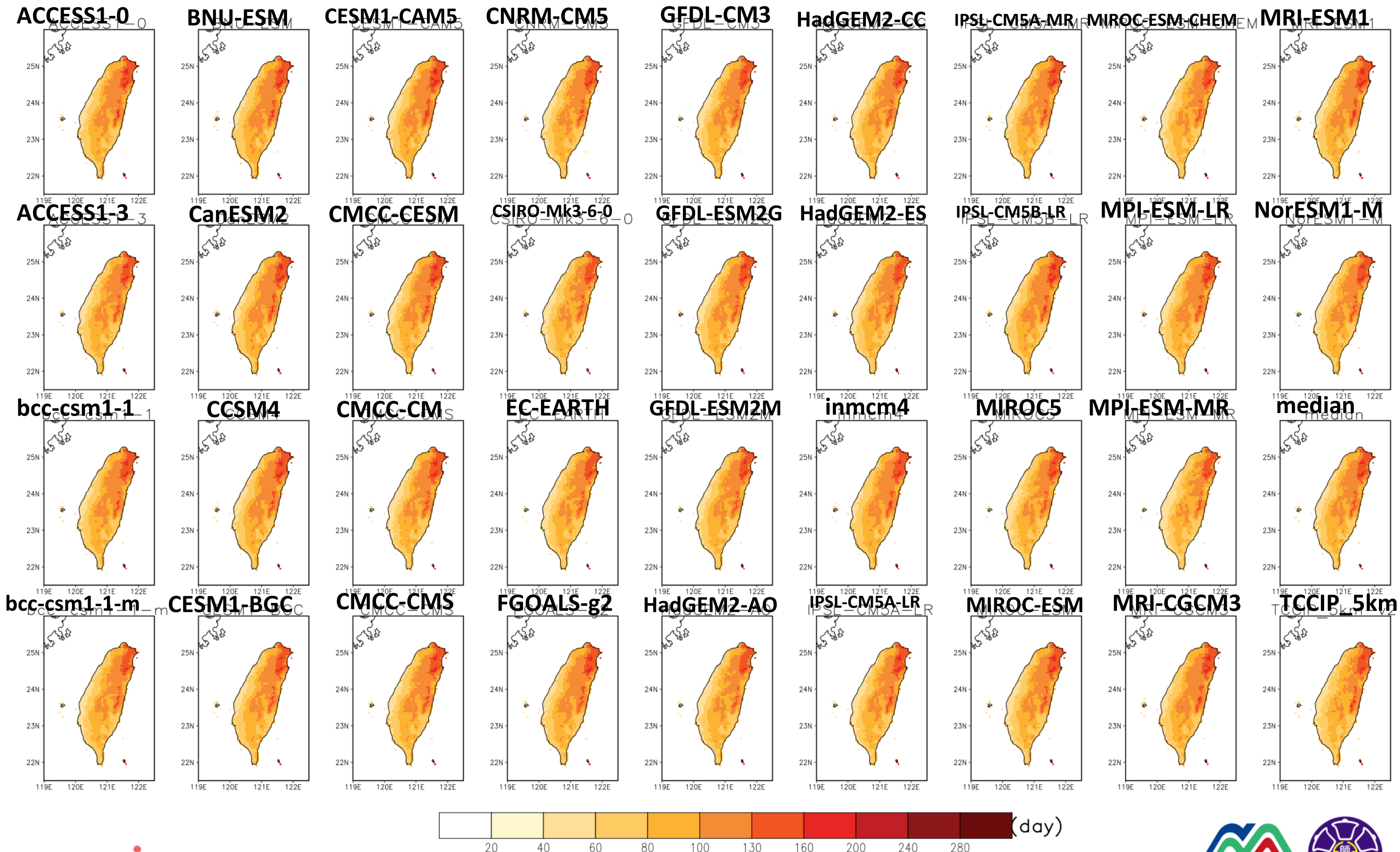
Wet day frequency from CMIP5 output interpolated

CMIP5 Model (Interpolation) RR1 (wet day frequency)



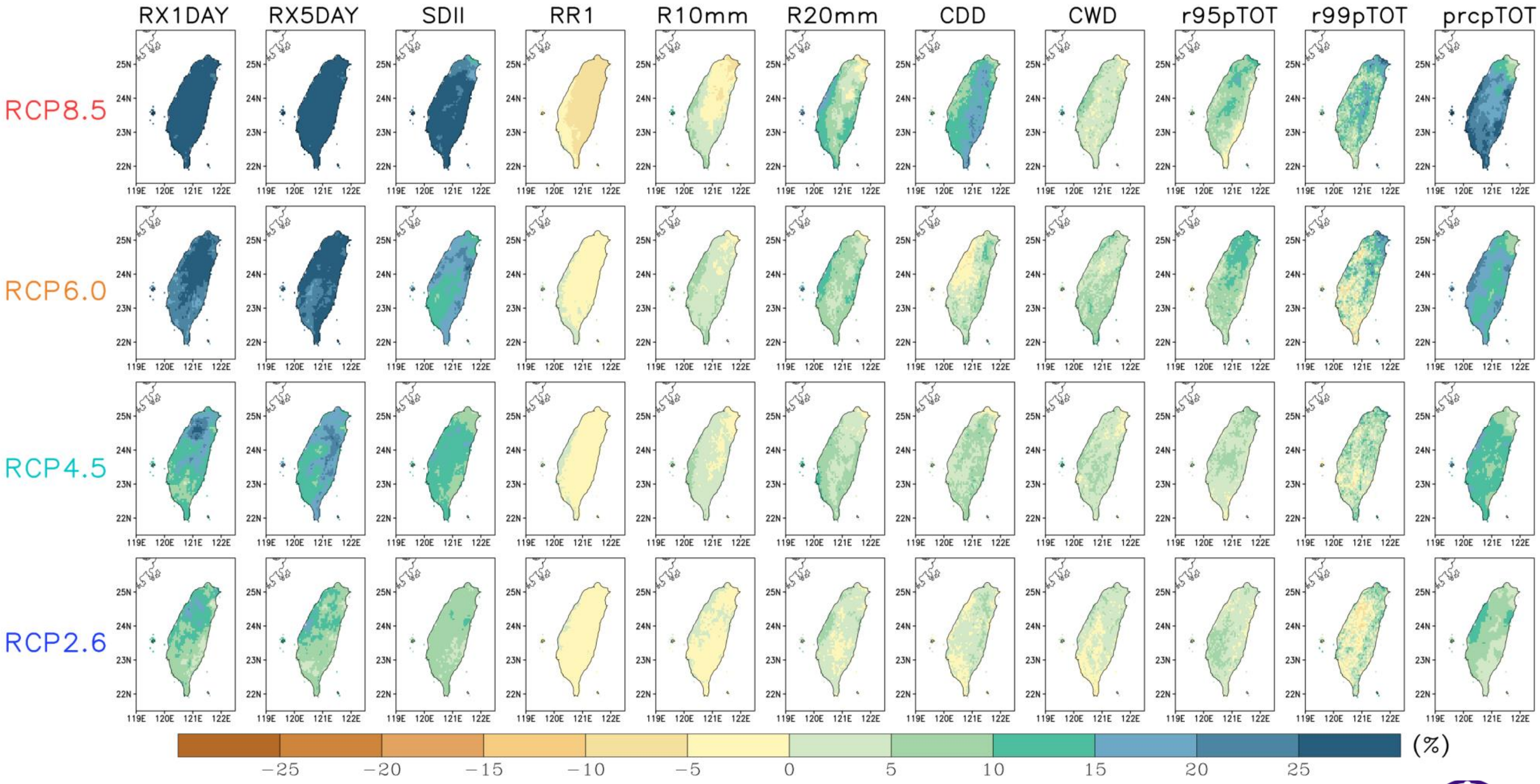
Wet day frequency from downscaled CMIP5

CMIP5 Model (Downscaled) RR1 (w31b10)



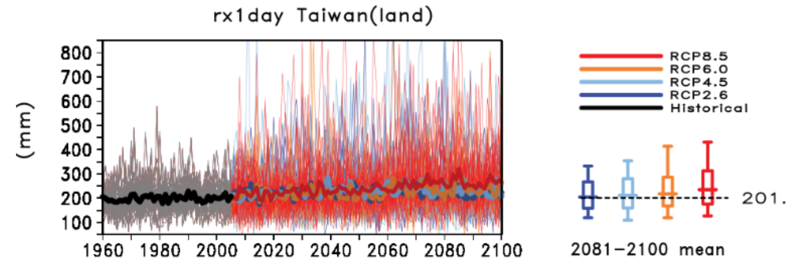
Projected Future Change of Extreme Indices

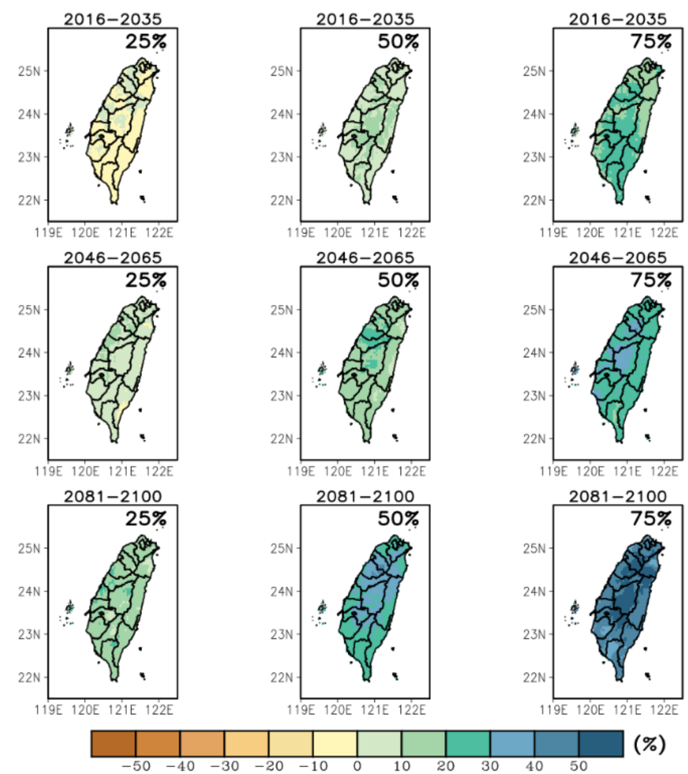
CMIP5 Model Projected Future Change of Rainfall Related Extreme Indices (Model Median, 2081-2100) Based on Downscaled Daily Data



Atlas of Future Projected Changes of Extreme Indices

區域	情境	世紀末 rx1day 百分比變化 (%)						
		最小	10	25	50	75	90	最大
北北基	rcp26	-12.8	-6.0	0.1	10.5	24.5	29.4	34.7
	rcp45	-10.1	-4.5	4.8	17.1	27.9	35.9	51.4
	rcp60	-3.7	1.6	15.9	24.9	33.6	49.2	65.7
	rcp85	-16.6	0.1	13.1	29.1	45.3	66.8	118.6
桃園	rcp26	-20.2	-3.0	3.9	12.5	22.0	28.6	39.0
	rcp45	-11.6	-5.4	7.0	19.2	29.4	36.9	43.1
	rcp60	1.5	6.1	15.8	26.7	33.2	45.0	64.4
	rcp85	-21.5	6.3	17.1	29.2	48.0	65.9	139.6
新竹	rcp26	-24.6	-1.3	5.2	15.3	24.0	32.8	50.9
	rcp45	-12.4	-5.7	5.5	20.7	34.1	41.5	54.5
	rcp60	3.0	9.3	19.2	29.7	36.2	53.8	64.4
	rcp85	-22.1	2.3	14.2	34.5	52.5	76.4	153.7
苗栗	rcp26	-27.3	-0.5	5.3	13.6	23.7	35.1	51.2
	rcp45	-11.4	-6.3	3.0	17.3	34.1	41.6	54.1
	rcp60	6.5	10.1	18.8	28.1	36.1	51.0	54.8
	rcp85	-23.1	-2.4	15.5	35.9	50.7	71.7	138.1
臺中	rcp26	-23.6	0.6	5.0	11.4	25.1	32.3	42.7
	rcp45	-11.6	-6.0	2.7	12.7	33.9	41.4	55.0
	rcp60	4.7	9.1	19.5	27.1	36.3	45.4	50.2
	rcp85	-23.8	-3.3	17.8	32.7	49.6	72.2	117.8
彰化	rcp26	-20.6	-0.5	2.9	10.5	22.2	34.8	41.6
	rcp45	-17.9	-3.8	3.1	11.1	28.6	39.3	44.9
	rcp60	1.8	3.6	16.1	22.3	32.4	43.8	46.8
	rcp85	-24.5	-3.7	19.5	28.8	45.1	75.2	105.4
南投	rcp26	-19.1	-0.7	4.7	10.9	25.5	35.0	43.3
	rcp45	-13.6	-5.5	3.4	12.9	33.9	43.2	57.4
	rcp60	3.4	8.5	18.6	28.0	35.8	46.3	49.9
	rcp85	-19.8	-2.8	16.1	31.7	53.6	79.8	106.7
雲林	rcp26	-15.6	-1.7	4.6	9.3	21.6	34.6	40.6
	rcp45	-16.2	-5.3	2.3	10.5	25.2	40.7	50.5
	rcp60	-4.1	0.3	13.4	20.6	32.1	46.6	50.6
	rcp85	-23.8	-5.5	18.1	28.7	44.9	78.3	100.6
嘉義	rcp26	-15.2	-2.0	3.8	8.7	24.9	33.4	39.3
	rcp45	-13.3	-4.3	3.4	11.3	27.5	40.1	52.2
	rcp60	-6.7	-2.2	12.9	22.4	31.7	45.0	49.4
	rcp85	-21.5	-4.7	13.3	31.0	48.7	80.7	100.8
臺南	rcp26	-11.0	-2.0	2.2	6.6	21.7	32.5	37.9
	rcp45	-13.5	-3.4	2.4	9.9	21.1	36.9	49.2
	rcp60	-11.4	-7.4	14.2	21.4	29.9	41.0	45.5
	rcp85	-23.1	-2.3	16.1	28.1	42.1	68.8	99.3
高雄	rcp26	-11.7	-4.9	1.6	6.1	22.7	32.7	43.0
	rcp45	-12.1	-6.6	0.0	7.9	21.8	35.4	52.4
	rcp60	-9.8	-3.1	11.6	22.6	29.6	38.9	41.0
	rcp85	-24.1	-2.3	13.2	28.7	45.3	64.3	90.8
屏東	rcp26	-12.9	-3.9	1.1	7.2	22.2	32.6	39.7
	rcp45	-15.4	-9.0	1.0	9.6	20.6	36.1	53.9
	rcp60	-10.3	-0.1	11.3	21.1	28.4	35.2	39.4
	rcp85	-26.2	3.9	15.7	26.4	40.7	57.4	79.3
宜蘭	rcp26	-12.4	-3.1	1.1	7.9	25.3	30.3	38.3
	rcp45	-9.8	-4.9	3.3	14.0	28.1	35.1	64.4
	rcp60	-5.8	0.4	16.5	25.3	33.7	50.1	59.5
	rcp85	-21.0	-4.8	10.6	30.0	48.9	75.6	100.3
花蓮	rcp26	-11.2	-3.5	1.7	8.3	23.6	30.6	39.6
	rcp45	-15.7	-5.4	4.2	14.1	29.3	40.3	62.6
	rcp60	-3.1	3.8	16.6	25.5	35.9	51.7	57.9
	rcp85	-19.7	-1.5	13.5	30.8	47.9	74.1	95.7
臺東	rcp26	-9.4	-5.6	-0.6	6.4	22.5	31.2	39.5
	rcp45	-20.3	-7.3	1.7	9.7	26.5	37.7	47.8
	rcp60	-3.4	3.4	9.5	19.8	31.0	41.6	67.0
	rcp85	-21.7	2.3	13.5	27.1	45.1	61.2	81.3
澎湖	rcp26	-10.3	-4.2	3.1	12.3	21.7	32.4	39.8
	rcp45	-6.2	-2.3	6.8	11.3	20.2	36.3	45.4
	rcp60	-10.8	0.6	11.8	20.4	35.2	42.6	53.1
	rcp85	-18.8	2.8	20.6	29.2	45.2	68.5	120.5





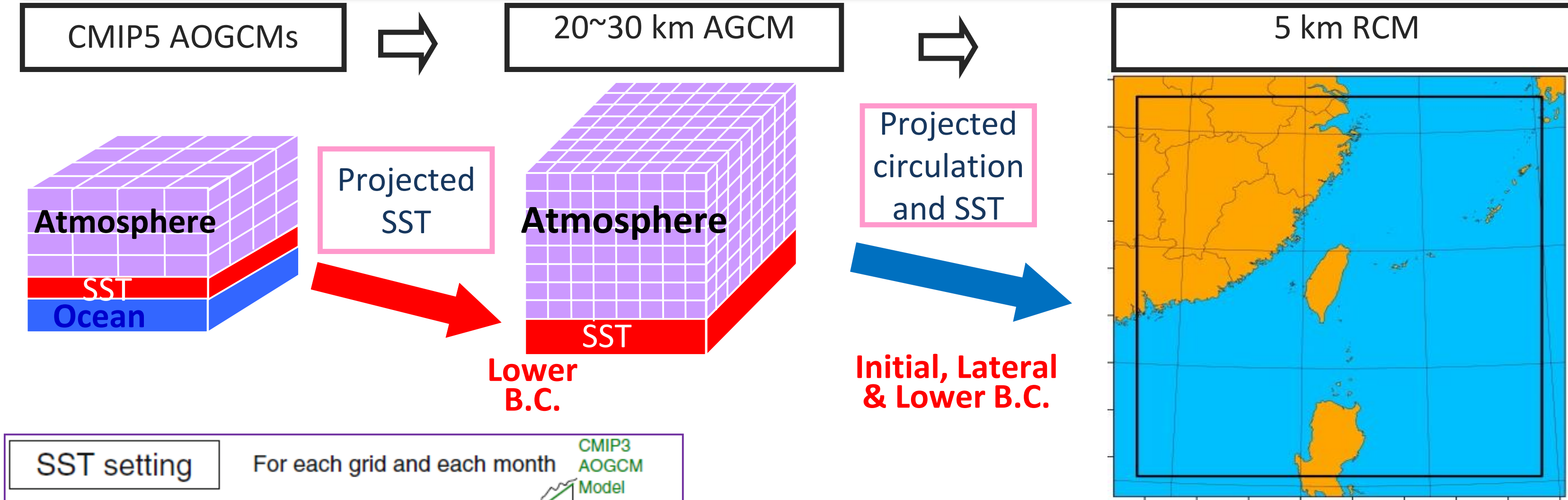
What's Next?

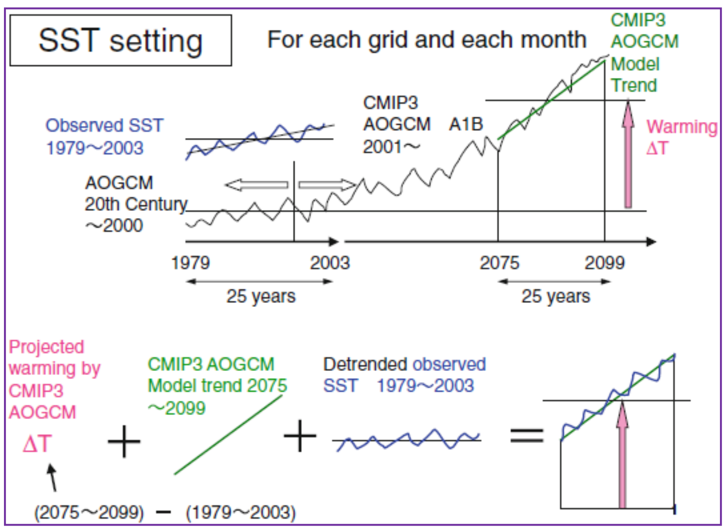
- **New Statistical Downscaling Methods:**
  1. **BCCA (Bias-Correction/Constructed Analogues; Maurer et al. 2010) combines spatial aggregation and daily quantile mapping with spatial information from a linear combination of historical analogues**
  2. **QMAP (Quantile MAPping; Gudmundsson et al. 2012) applies quantile mapping to daily GCM/RCM outputs that have been interpolated to the high-resolution grid using the climate imprint method of Hunter and Meentemeyer (2005) – aka BCCI**
  3. **BCCAQ (BCCA with Quantile MAPping reordering) is a modified BCCA using QMAP in addition to BCCA post-processing (Cannon et al., 2015)**

- **Use Dynamical Downscaling Result as Pseudo-Observation to:**
  1. **Compare the Performance of Different Statistical Downscaling Methods.**
  2. **Test the Stationarity Assumption under Climate Change.**

Dynamical downscaling from ~25km to ~5km

Time-Slice Experiments of AGCM **MRI-AGCM** with **20km** resolution / **HiRAM** with ~**25km** resolution **and RCM**





Kusunoki et al. (2011)

WRF 3.5.1 as RCM

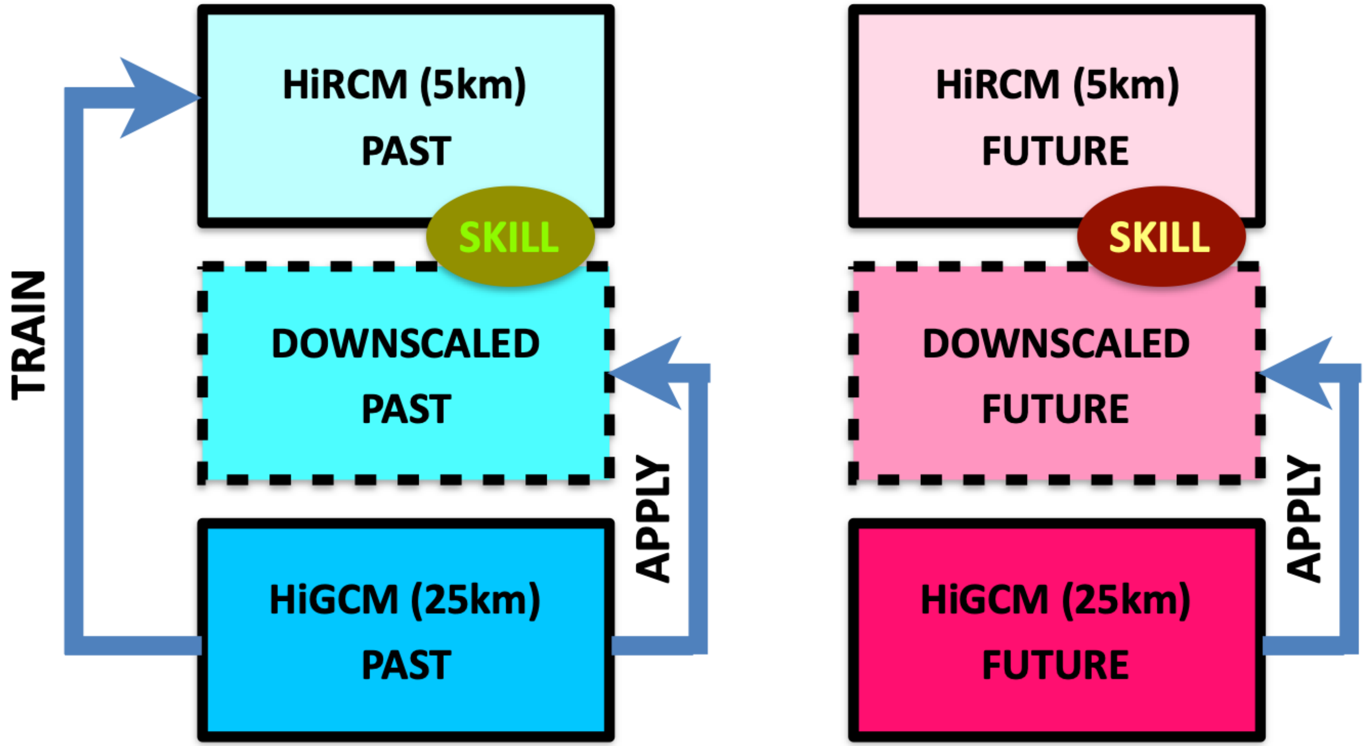
- ❑ Noah land surface
- ❑ YSU Boundary Layer
- ❑ M.-Obukhov sfc layer
- ❑ CAM3 radiation
- ❑ WSM5 microphysics
- ❑ No cumulus for May ~Aug. KF cumulus for others.
- ❑ Spectral nudging fot U, V, Φ and T, not in PBL.
- ❑ Use RCP8.5 GHG in radiation scheme.
- ❑ Taiwan land use replace MODIS/USGS data.
- ❑ Re-initialize ATM on Jan. 1st of every year.

Perfect Model Experimental Design

PERFECT MODEL EXPERIMENTAL DESIGN

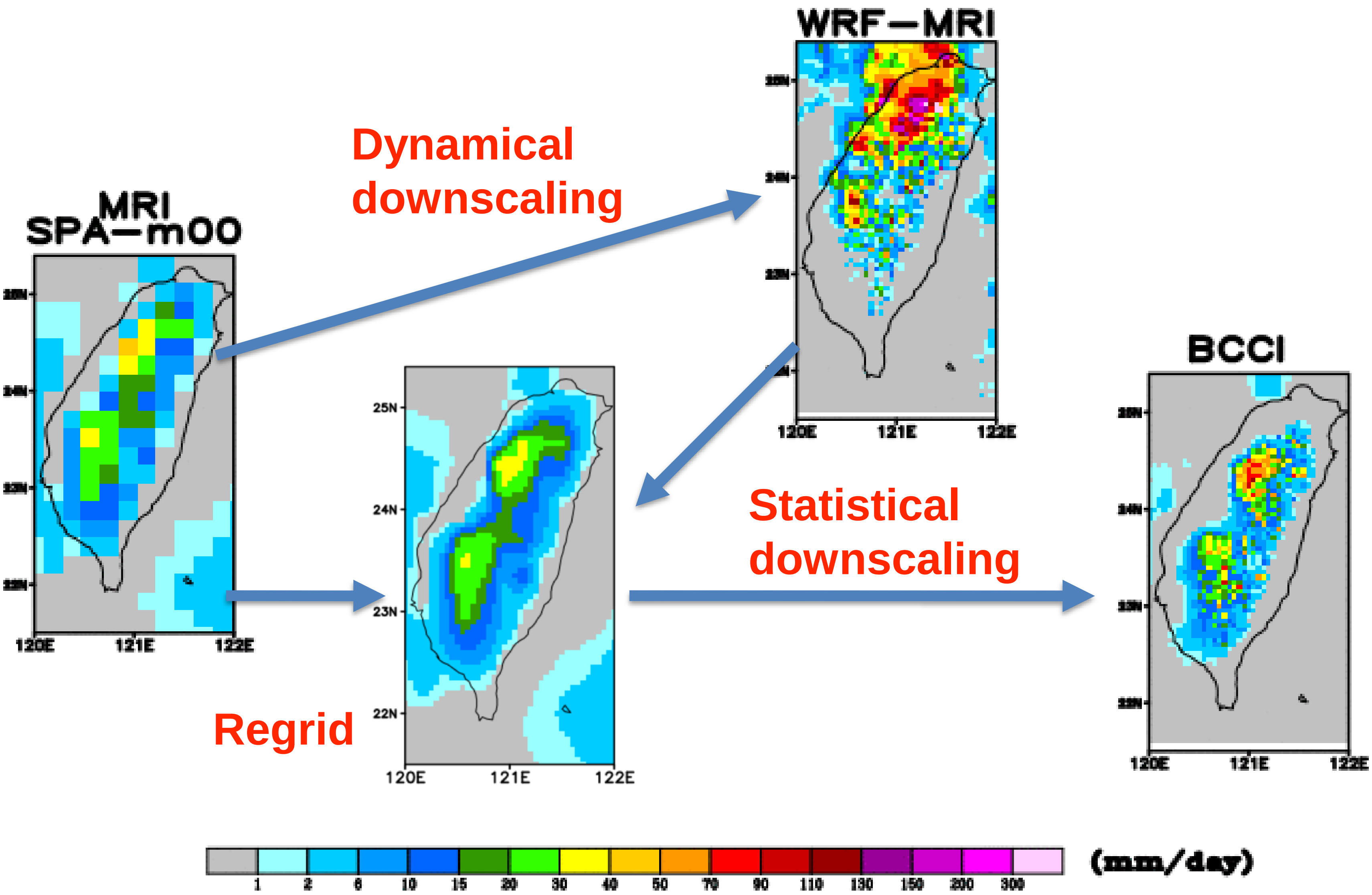
In The Perfect Model World

Now we can compare skill past vs. skill future to assess the validity of "The Stationarity Assumption"



PERFECT MODEL EXPERIMENTAL DESIGN

In The Perfect Model World

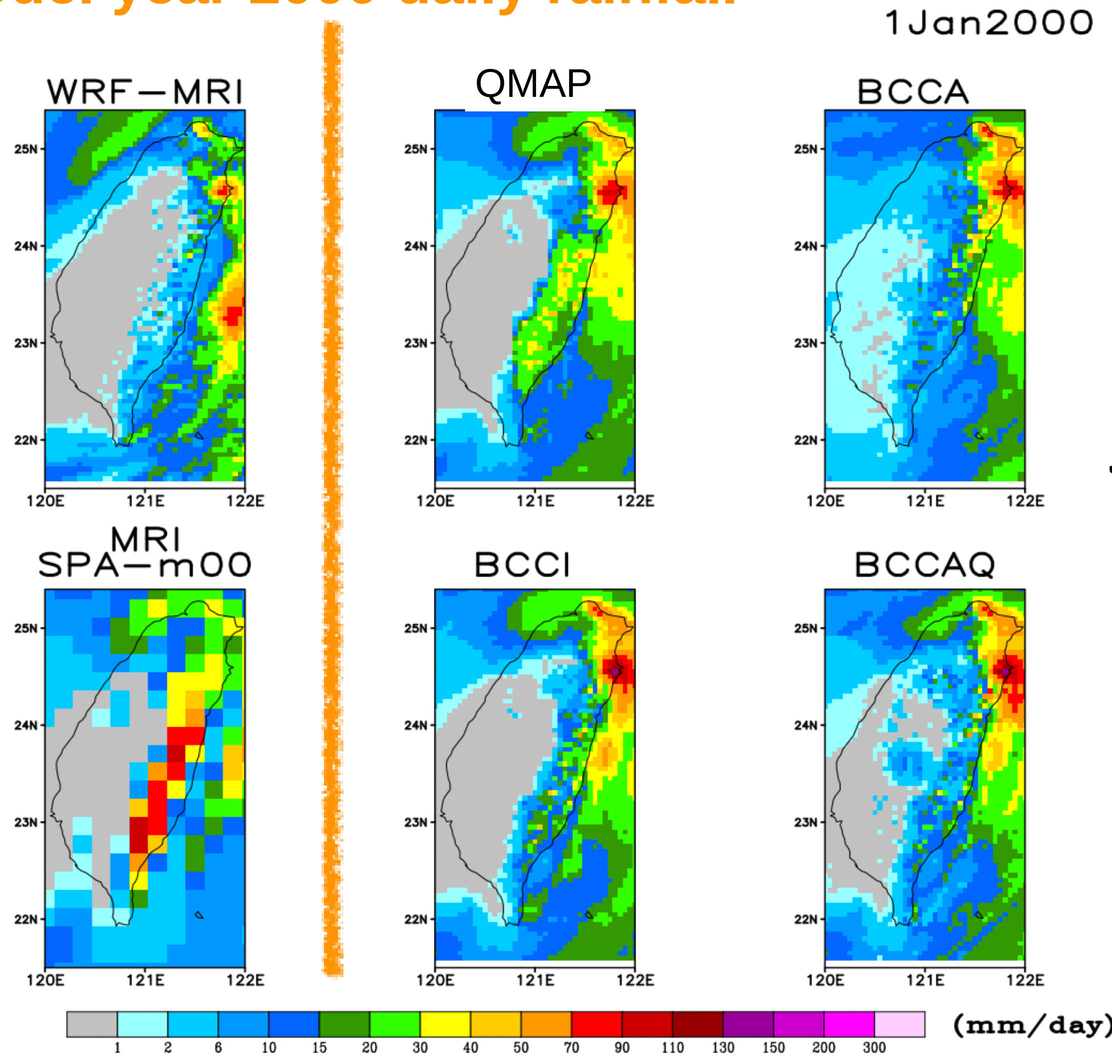


Statistical vs. Dynamical Downscaling

Model year 2000 daily rainfall

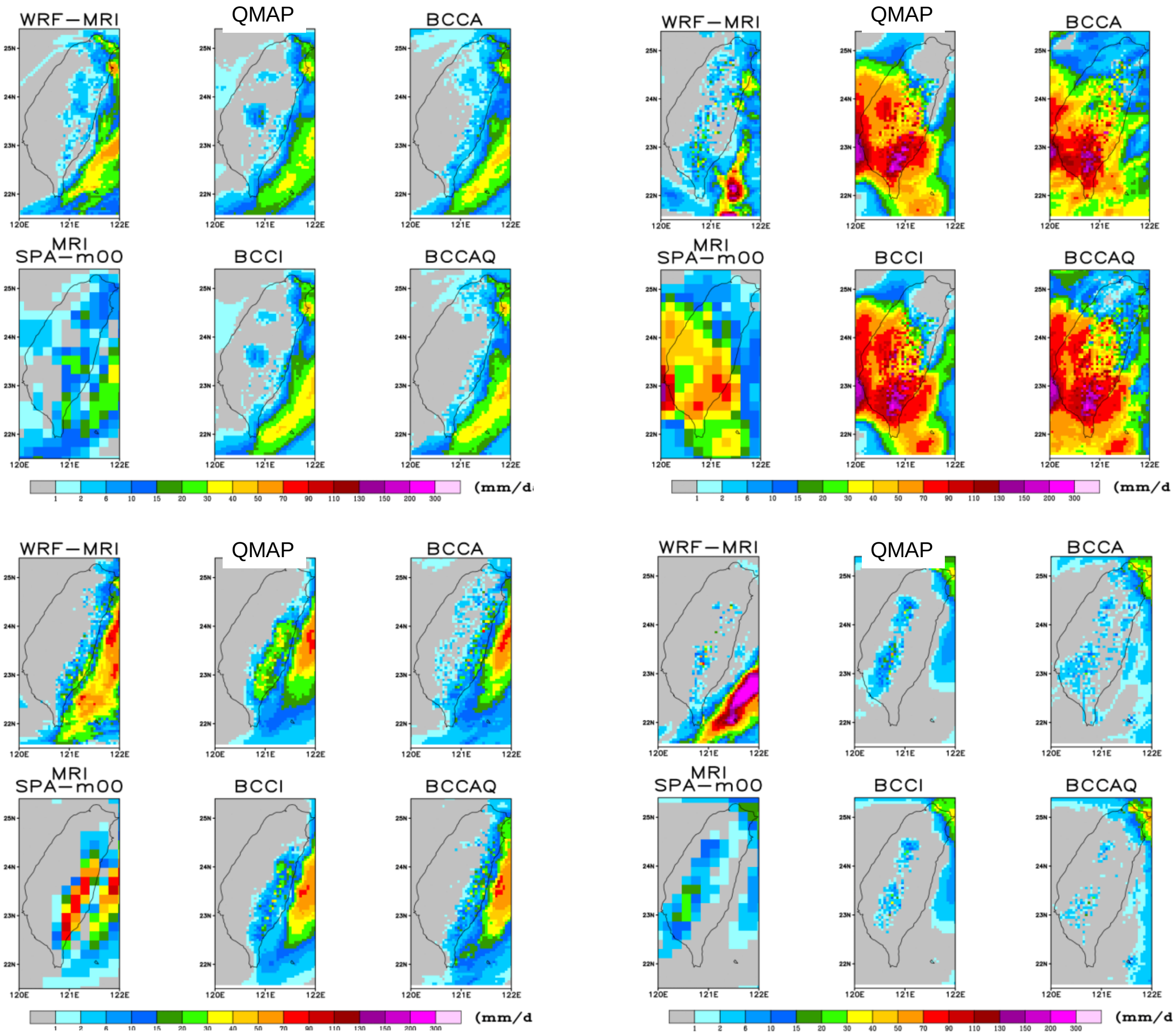
5km
MRI/WRF

20km
MRI



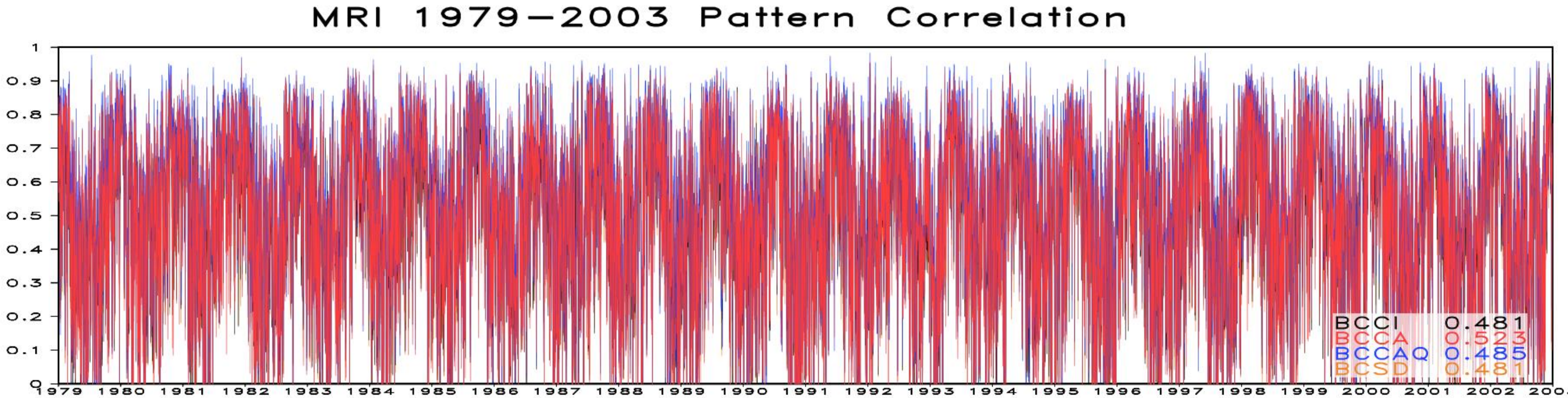
5km
ESD

Statistical vs. Dynamical Downscaling

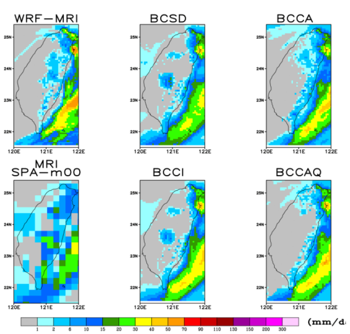


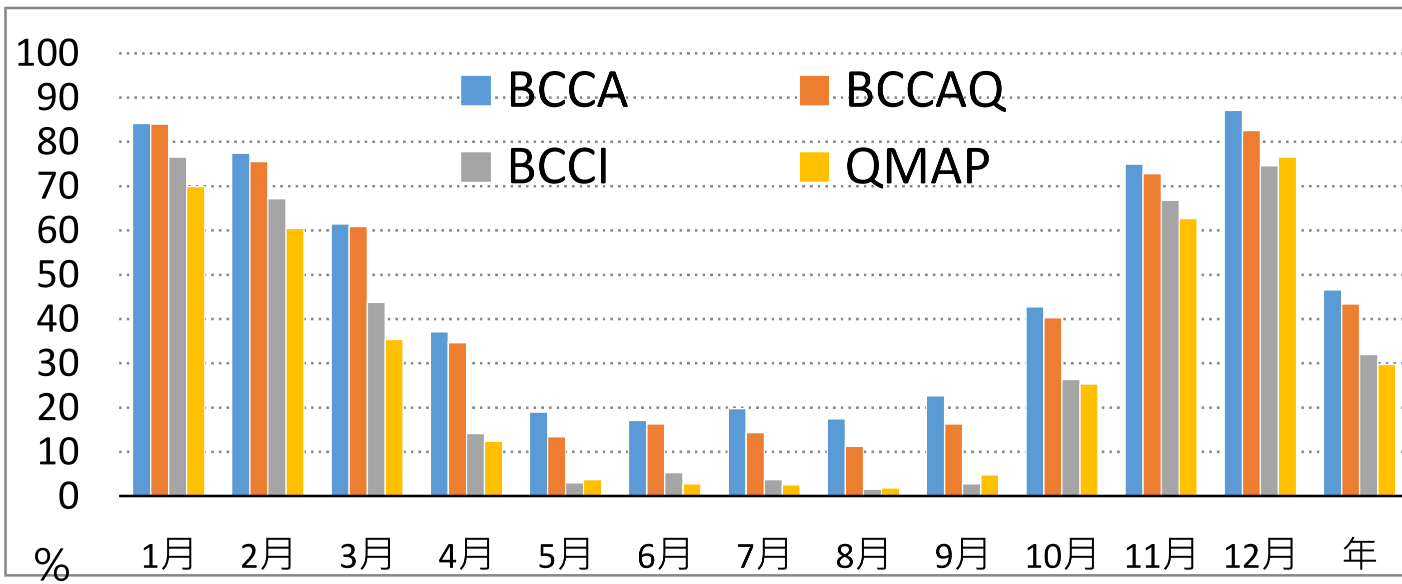
Daily Rainfall Comparison Examples

Comparison between different ESDs

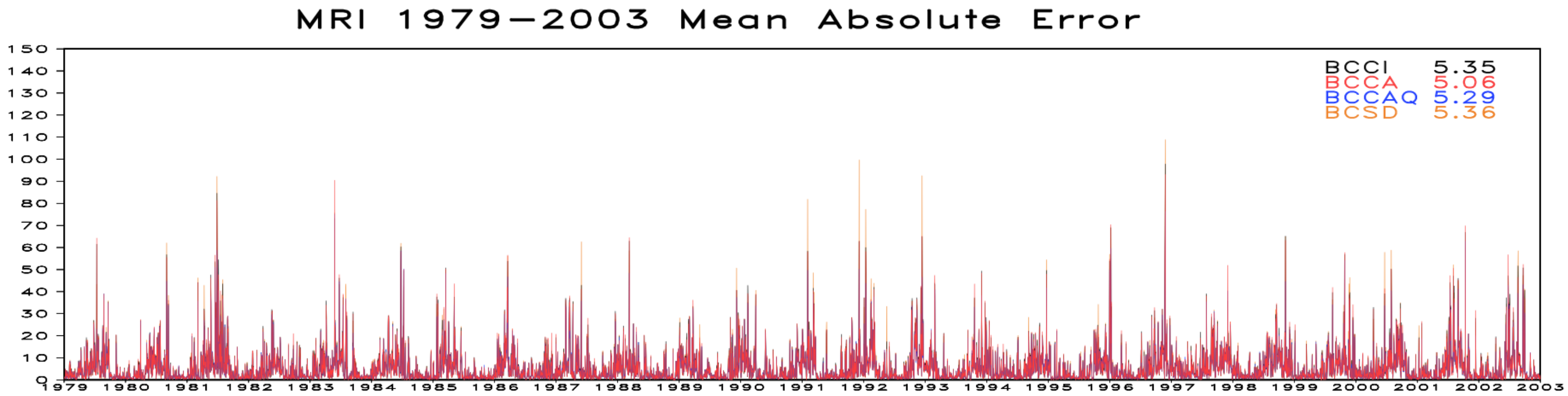


Percentage of time when r(MRI/WRF,ESD) is larger than r(MRI,ESD)

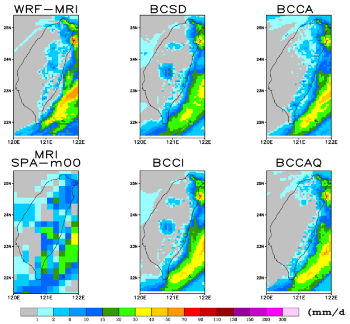


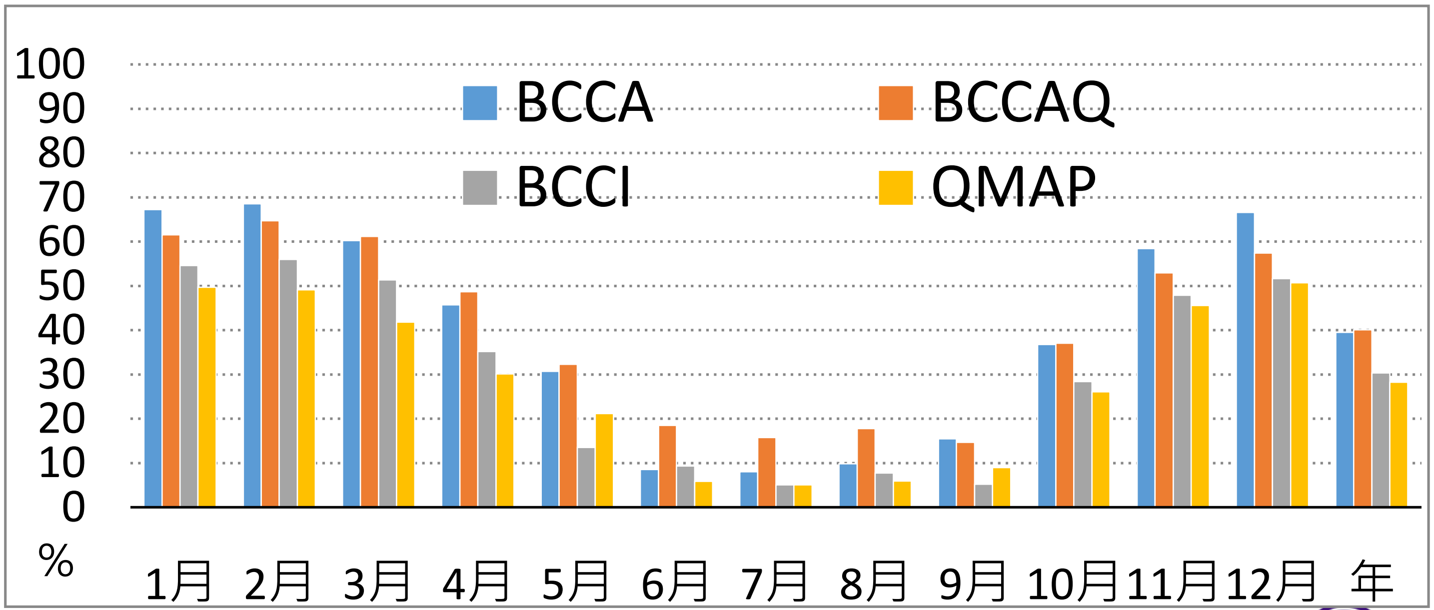


Comparison between different ESDs

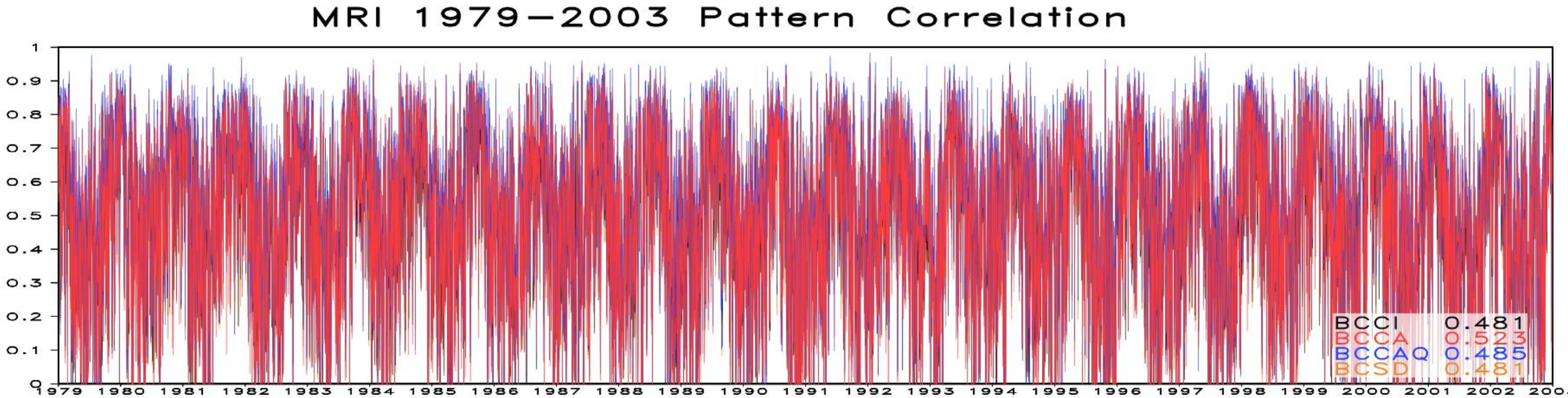


Percentage of time when MAE(MRI/WRF,ESD) is smaller than MAE(MRI,ESD)

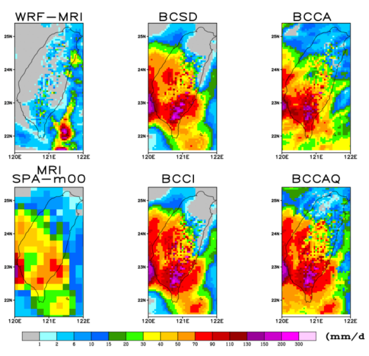


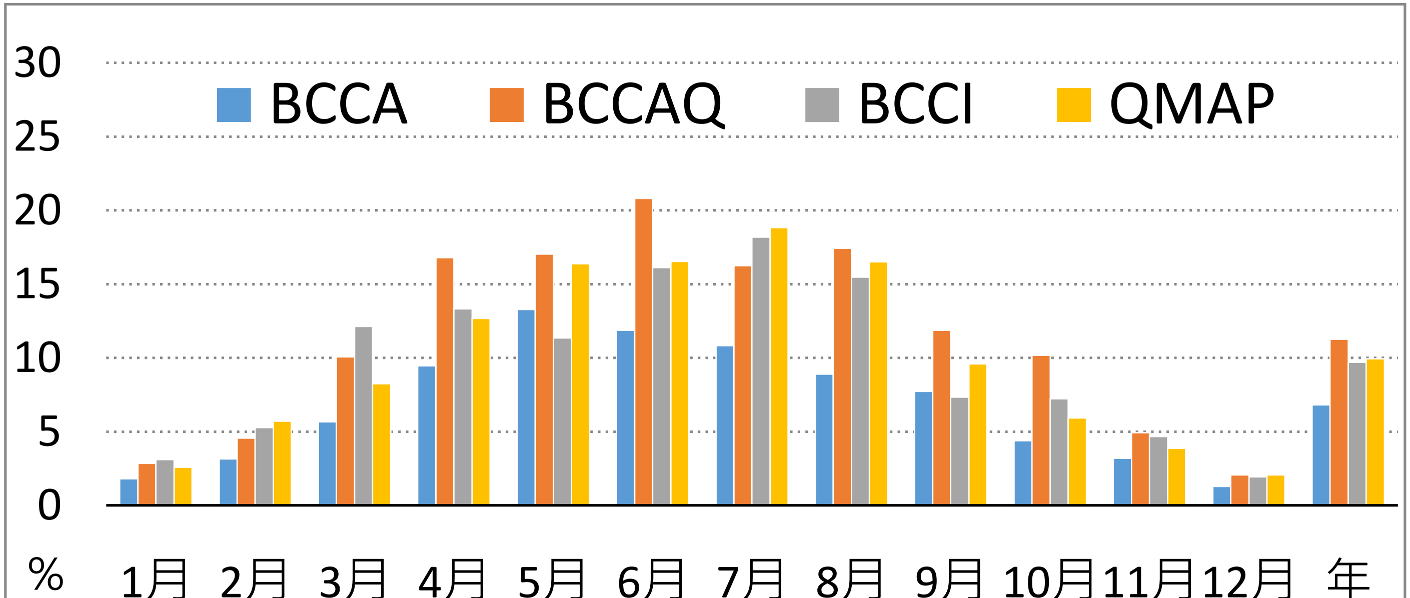


Comparison between different ESDs

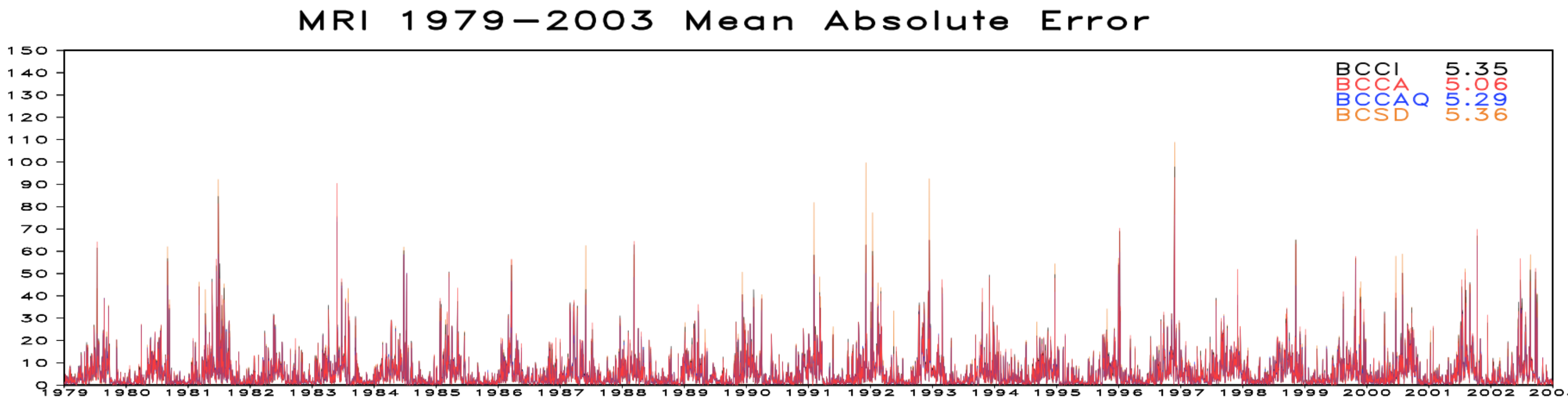


Percentage of time when r(MRI/WRF,ESD) is worse than r(MRI/WRF,MRI)

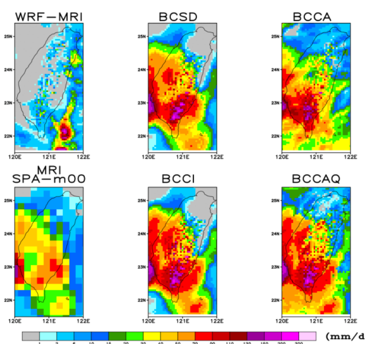


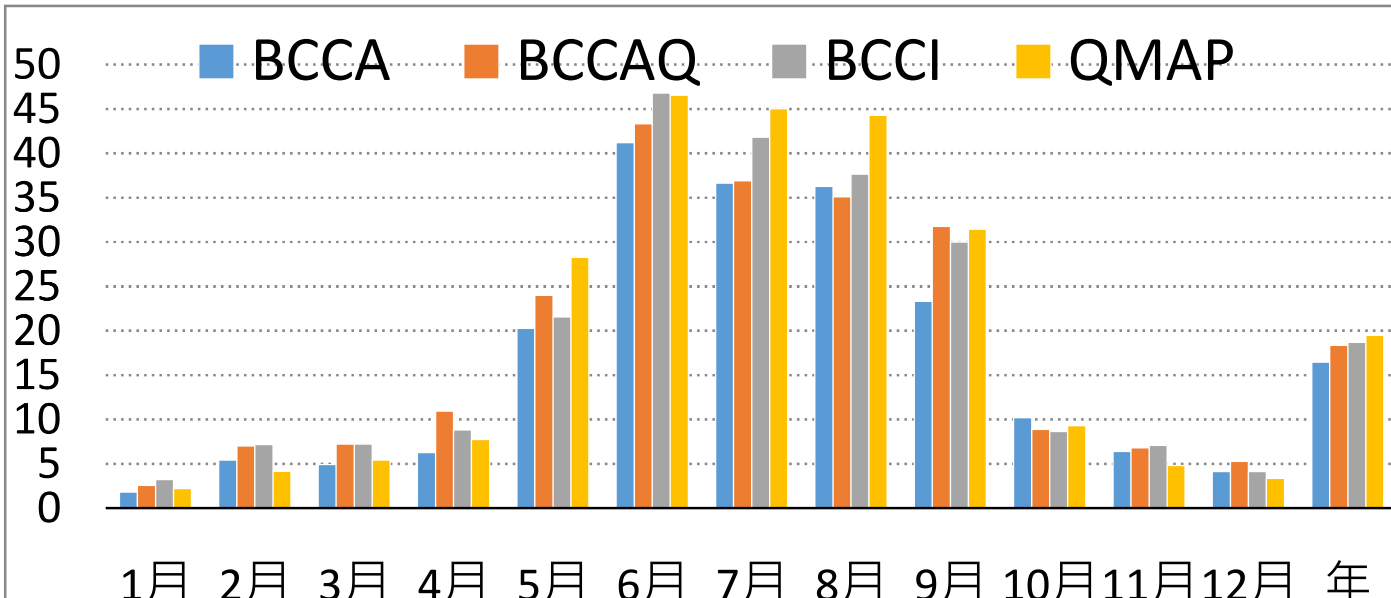


Comparison between different ESDs



Percentage of time when MAE(MRI/WRF,ESD) is larger than MAE(MRI/WRF, MRI)

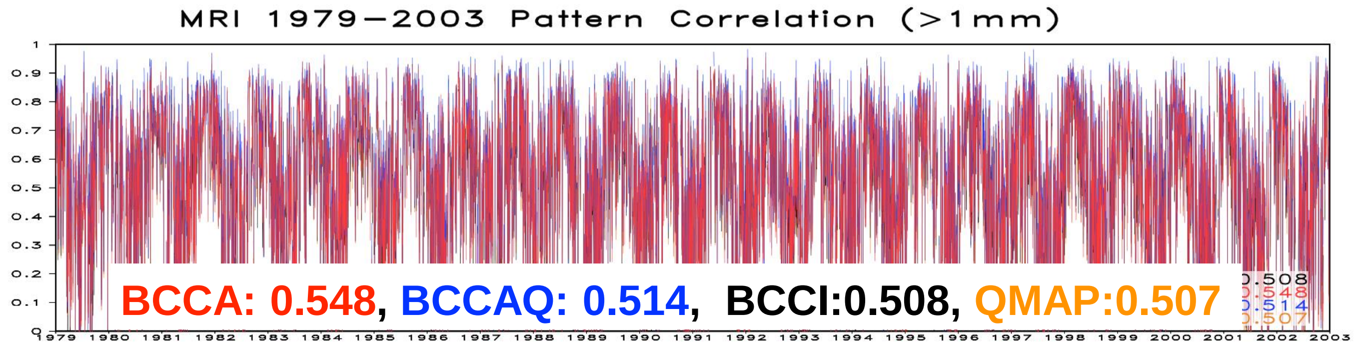




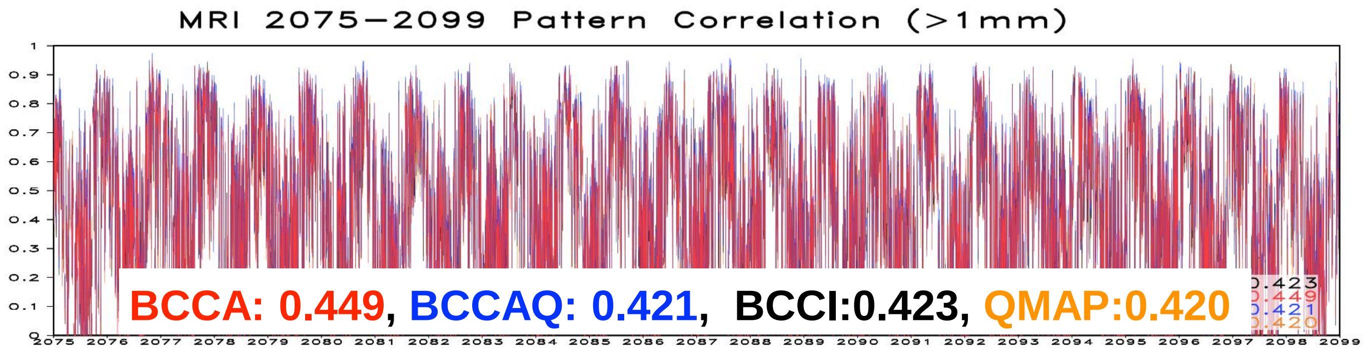
Stationarity Assumption

Pattern correlation for area mean daily rainfall >1mm

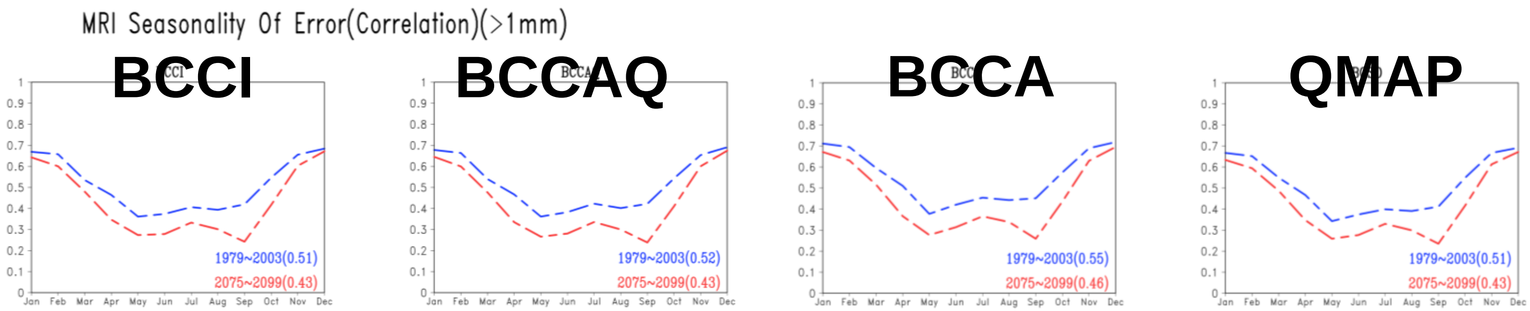
Present



Future Projection



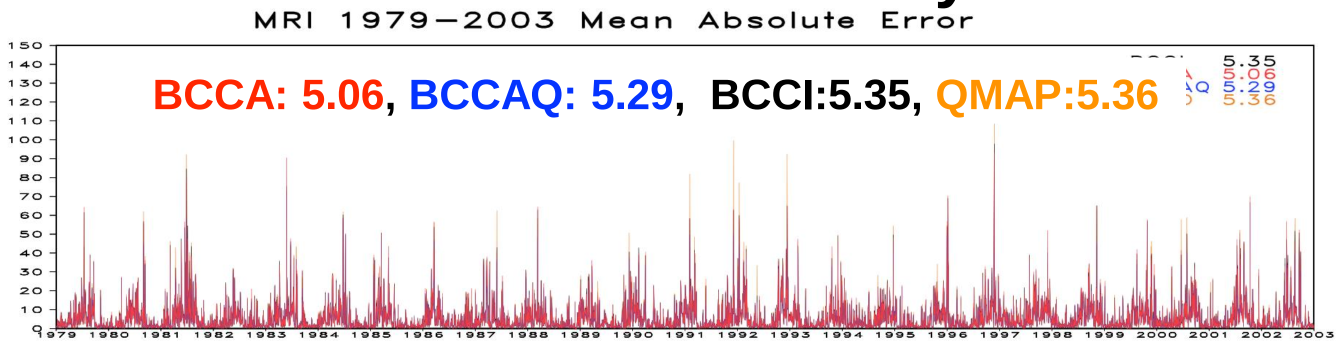
Seasonality



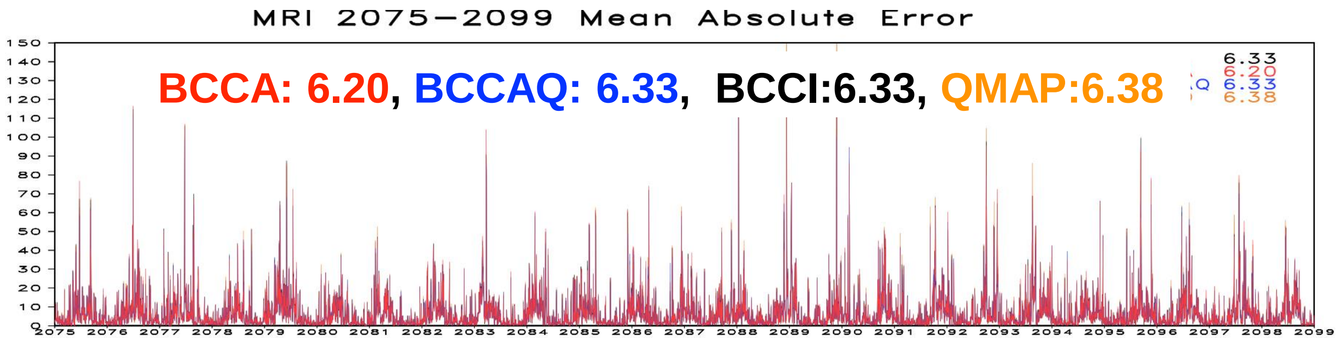
Stationarity Assumption

Mean Absolute Error of Daily Rainfall

Present

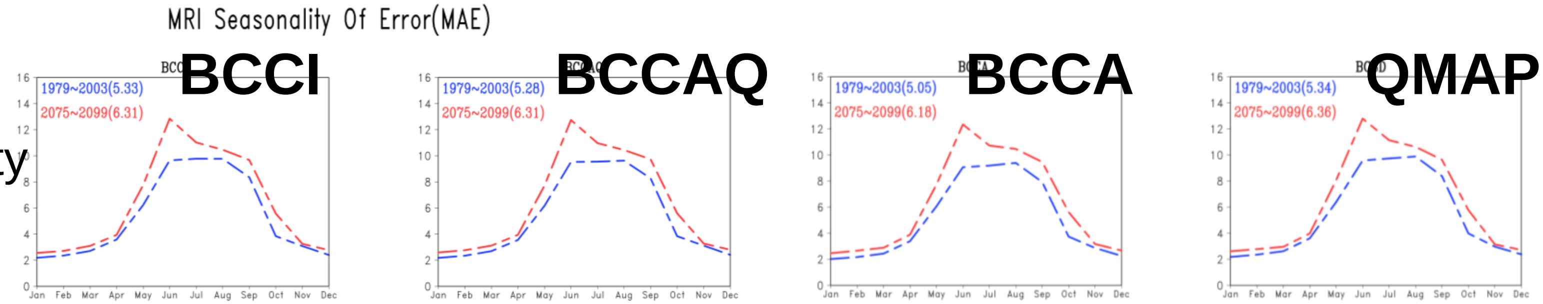


Future Projection



Ratio > 1→ "Stationarity assumption" violated (larger errors in future)

Seasonality

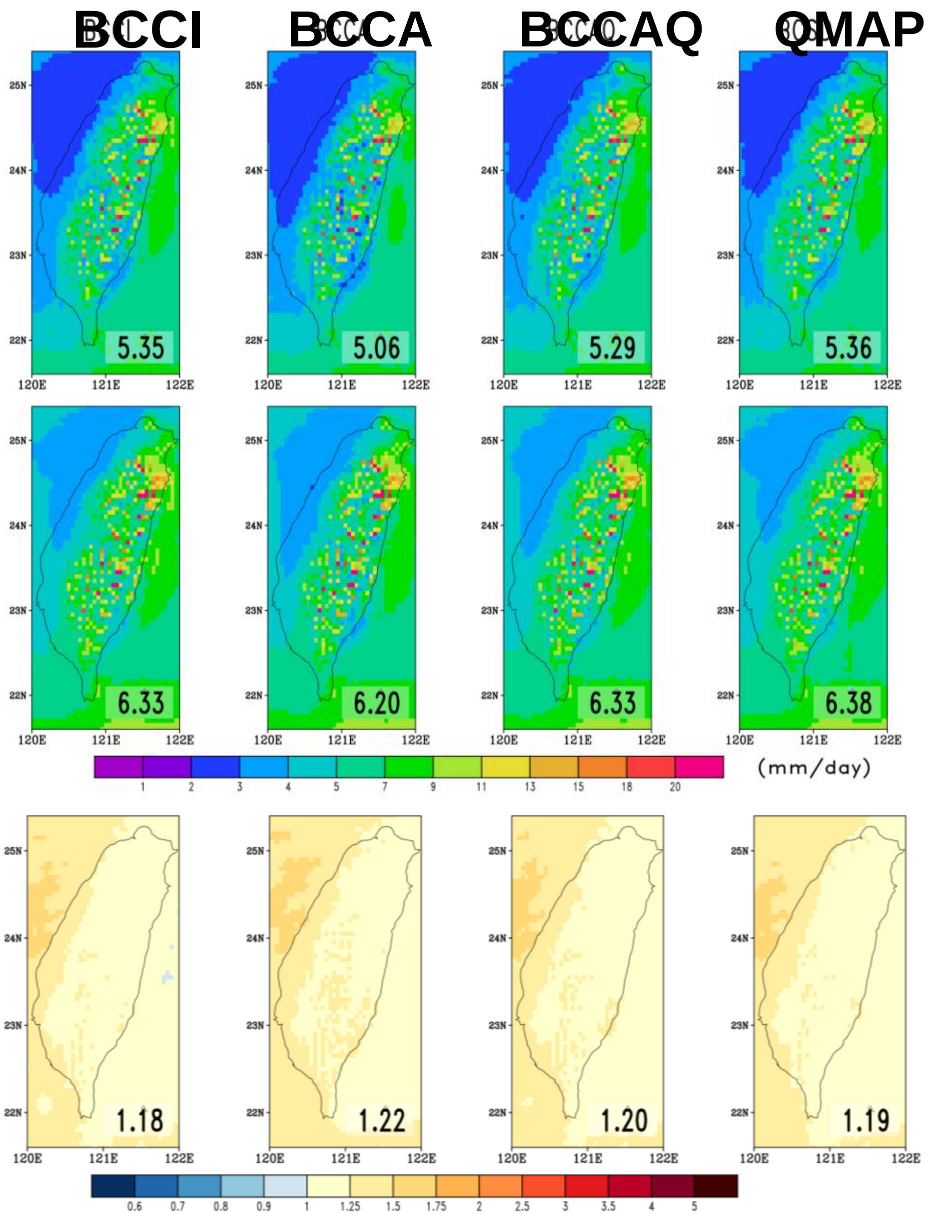


Stationarity Assumption

1979-2003

2075-2099

Ratio



Mean Absolute Error of Daily Rainfall

Ratio > 1→ "Stationarity assumption" violated (larger errors in future)

Summary and Concluding Remarks

- **Statistical approach is a relatively simple and cheap alternative to capture full model and scenario uncertainties.**
- **Statistical downscaling methods applied to CMIP5 data archive can effectively remove the model bias and adjust spatial scale dependence of extreme indices.**
- **Using dynamical downscaling result as surrogate observation for daily data statistical downscaling, different statistical downscaling methods will be compared for the their relative strength in reproducing "pseudo-observation" and tested for their validity of stationarity assumption under climate change.**

The End