Testing the stationary assumption of statistical downscaling using dynamical downscaling model output as pseudo observation

Cheng-Ta Chen[1], Shou-Li Lin[1], Tzu-Tai Hsi[1], and Chao-Tzuen Cheng [2]

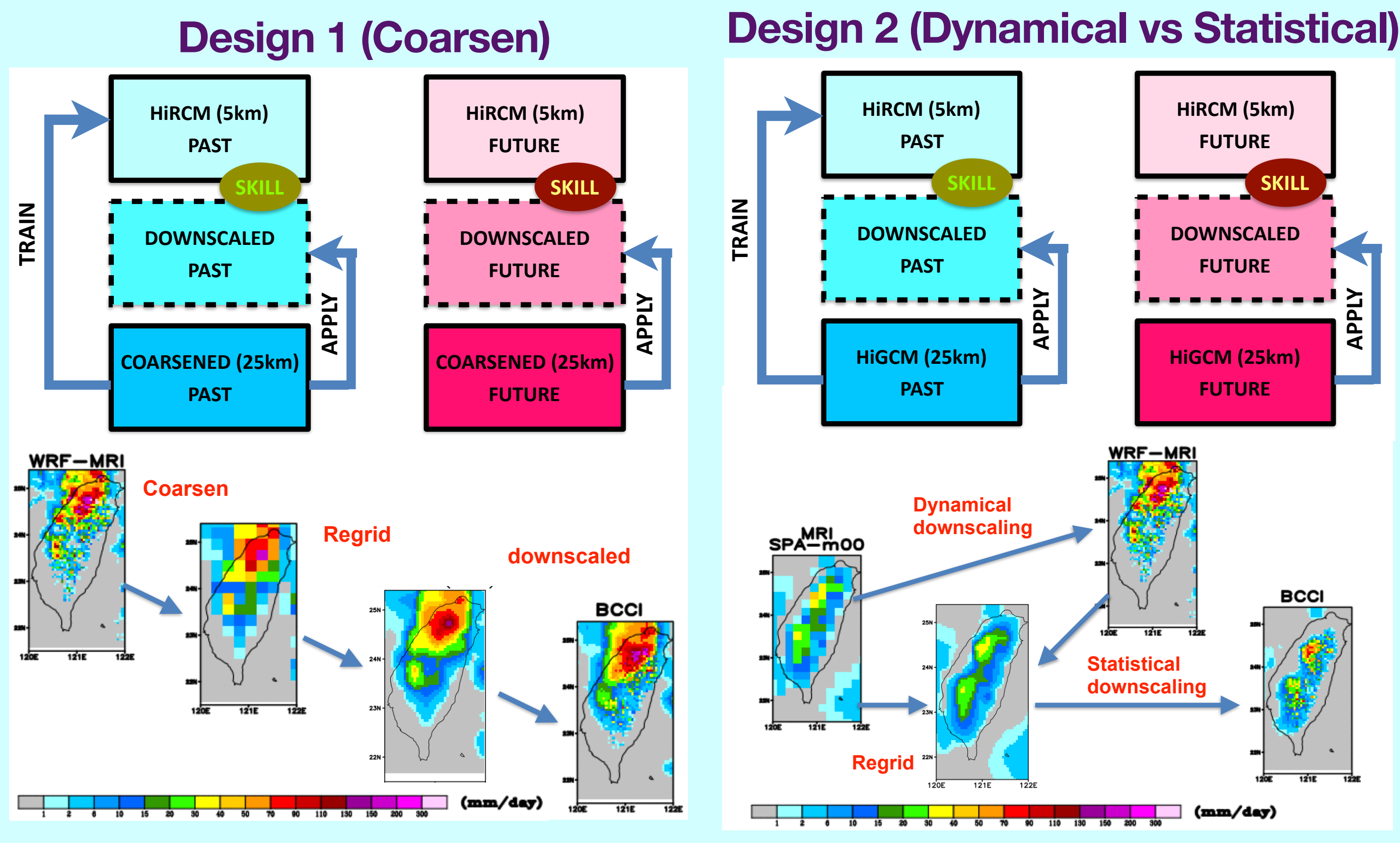[1]National Taiwan Normal University, Department of Earth Sciences, Taipei, Taiwan

[2]National Science and Technology Center for Disaster Reduction, New Taipei, Taiwan
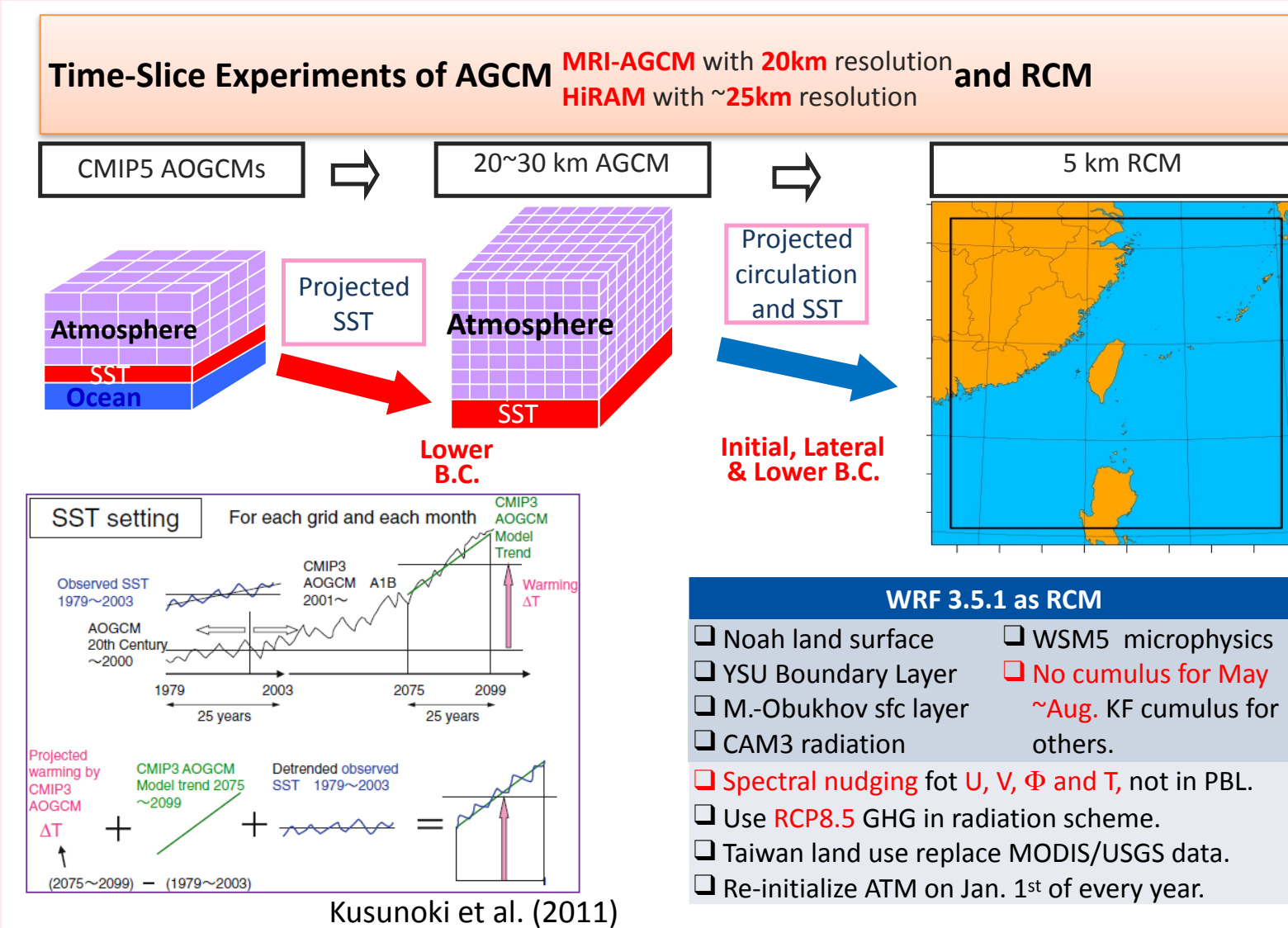
Testing stationary assumption

- "Stationarity Assumption" -- All ESD methods assume: historical relations → valid in future (but climate has changed!)
- Readily tested in "Perfect Model" world (future obs exist)
- Perfect Model: Use GCM/RCM output as both "obs" and "model"

Perfect Model Experiment Design

"The Stationarity..."

Design 1 (Coarsen)   **Design 2 (Dynamical vs Statistical)**

Dynamical downscaling from ~25km to ~5km

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

CMIP5 AOGCMs ⇒ 20~30km AGCM ⇒ 5 km RCM

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 for 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.

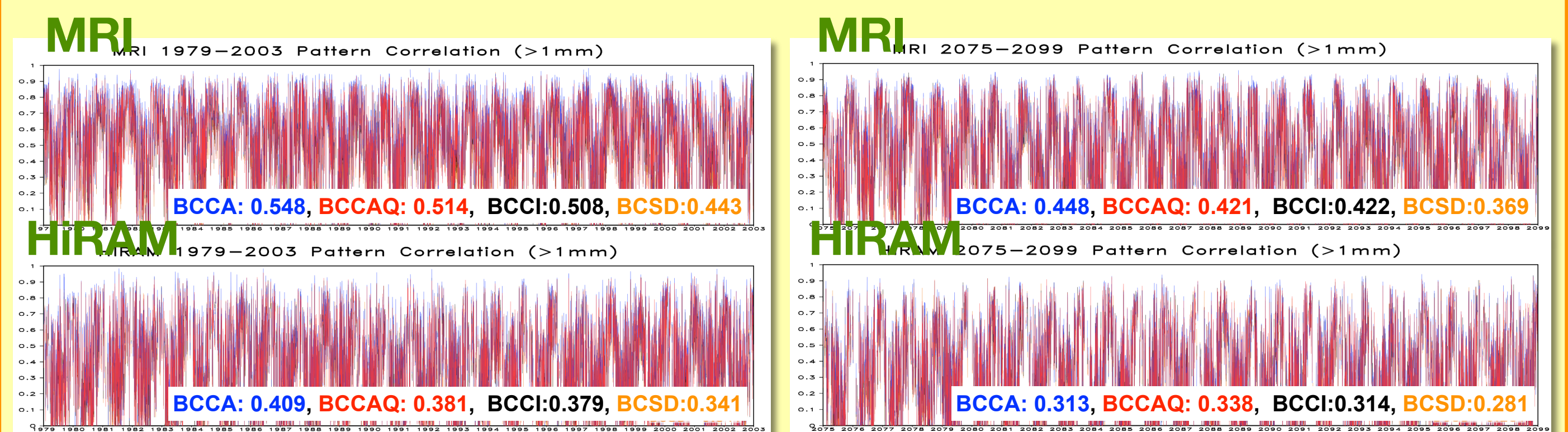Kusunoki et al. (2011)

Statistical downscaling Methods

- **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
- **BCCI** (or QMAP, Quantile MAPing; 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)
- **BCCAQ** (BCCA with Quantile MAPing reordering) is a modified BCCA using QMAP in addition to BCCA post-processing (Cannon et al., 2015)
- **BCSD** (Bias-Correction/Spatial Downscaling); applies quantile mapping to daily GCM/RCM outputs that have been interpolated to the high-resolution grid using optimal selection of data window and mapping interval (Wood et al. 2004)

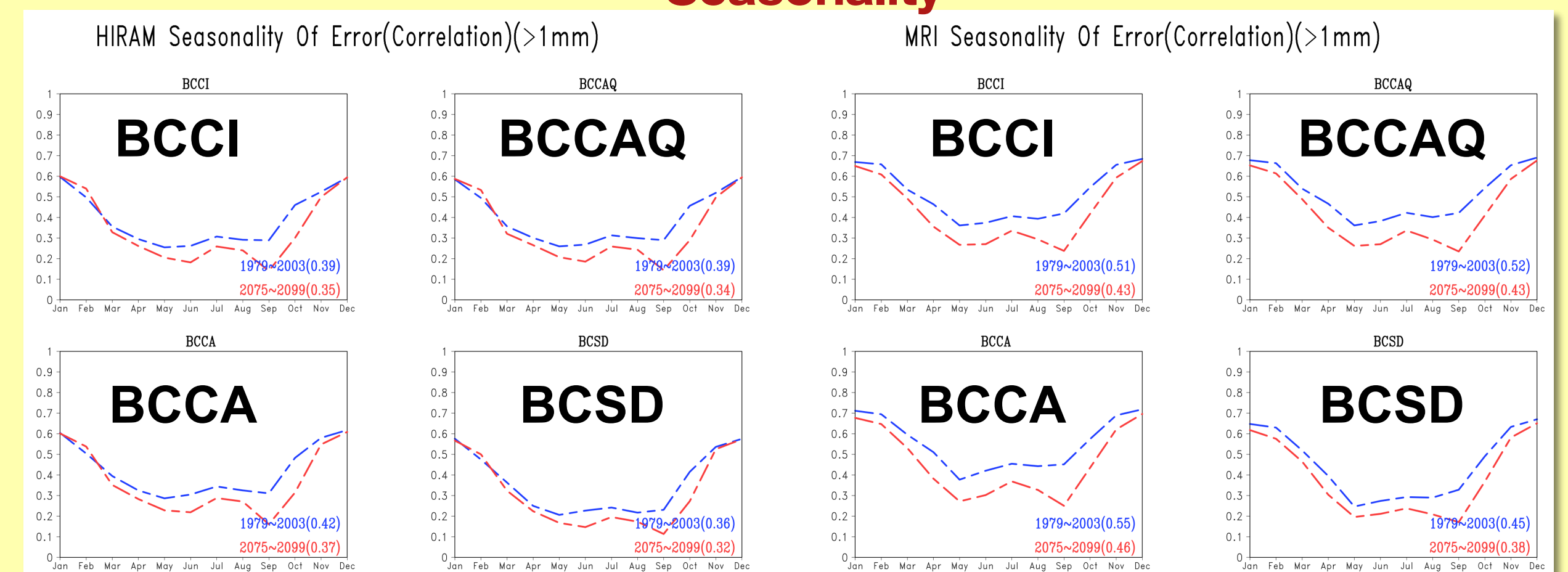## Design 2 (Dynamical vs Statistical)

Pattern correlation for area mean daily rainfall >1mm

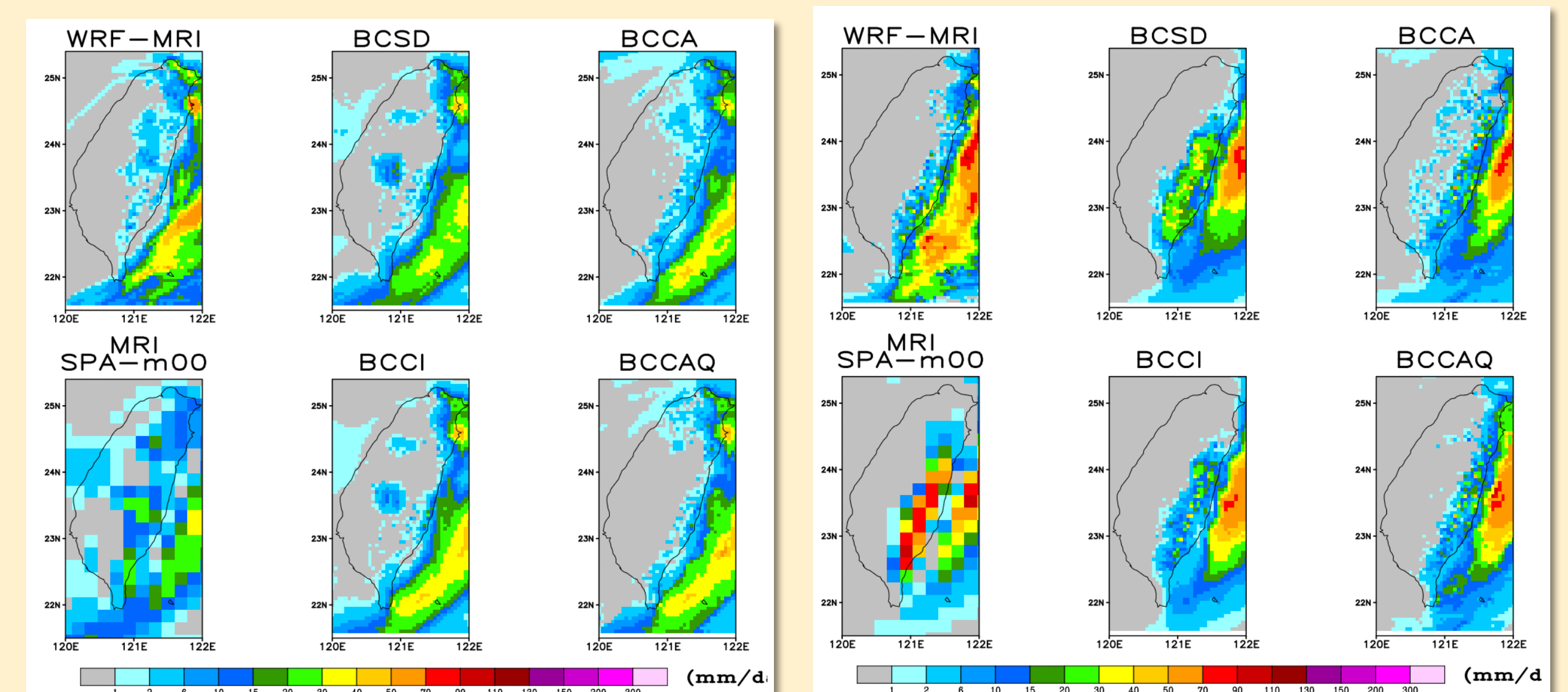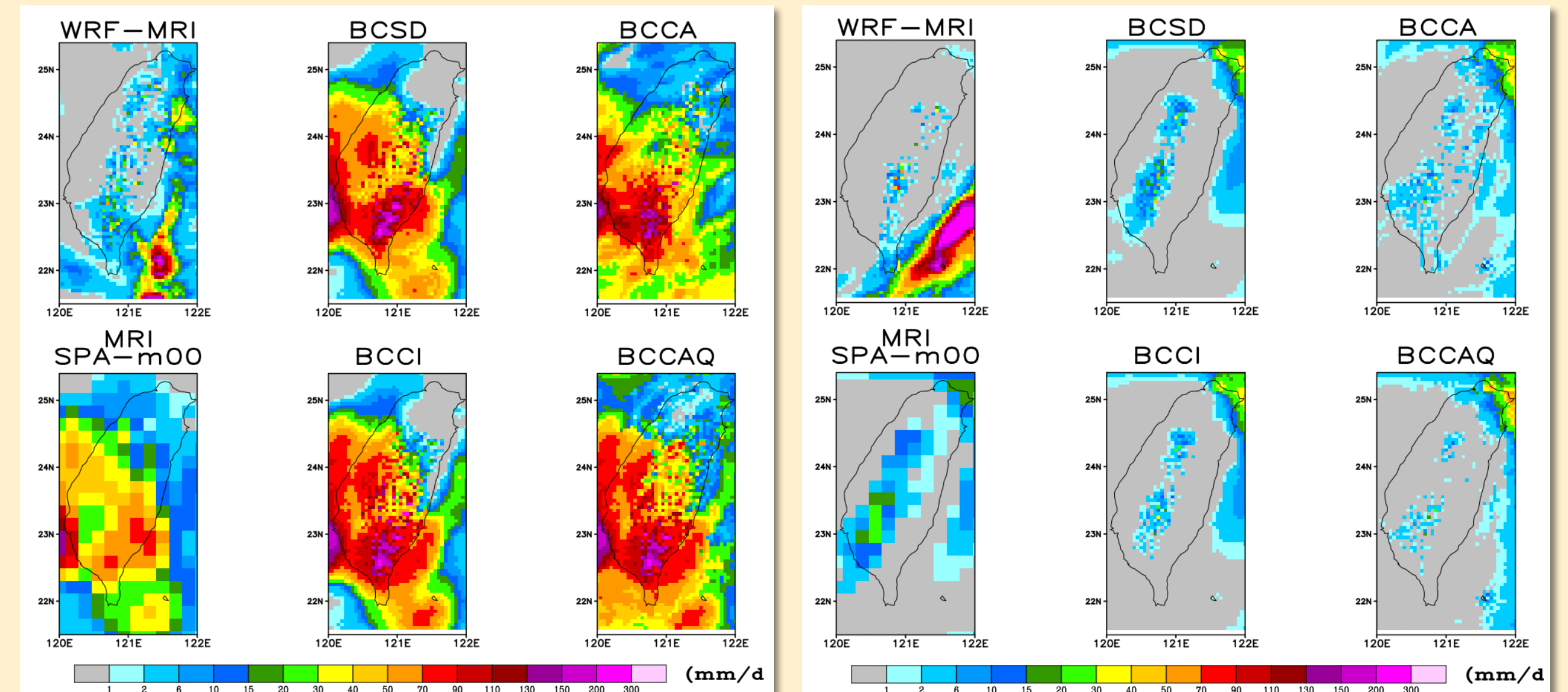**Present Climate 1979-2003 (Training)**   **RCP 8.5 2075-2099 (Projection)**

MRI 1979-2003: BCCA: 0.548, BCCAQ: 0.514, BCCI:0.508, BCSD:0.443
MRI 2075-2099: BCCA: 0.448, BCCAQ: 0.421, BCCI:0.422, BCSD:0.369
HiRAM 1979-2003: BCCA: 0.409, BCCAQ: 0.381, BCCI: 0.379, BCSD:0.341
HiRAM 2075-2099: BCCA: 0.313, BCCAQ: 0.338, BCCI:0.314, BCSD:0.281

Seasonality

HIRAM Seasonality Of Error(Correlation)(>1mm) — BCCI, BCCAQ, BCCA, BCSD
MRI Seasonality Of Error(Correlation)(>1mm) — BCCI, BCCAQ, BCCA, BCSD

Design 1 (Coarsen)

Pattern correlation for area mean daily rainfall >1mm

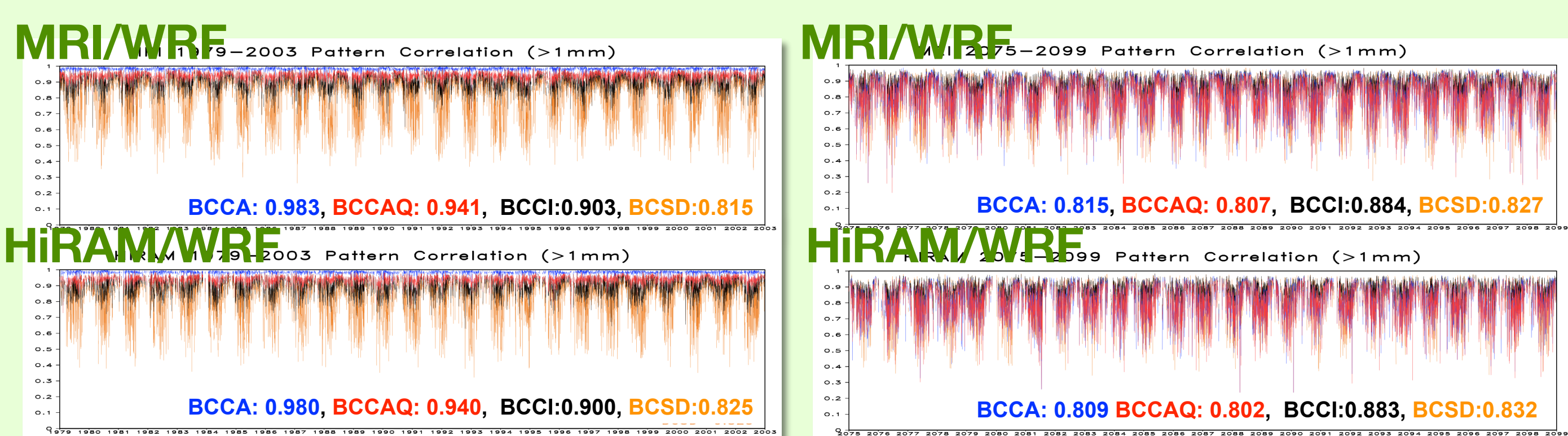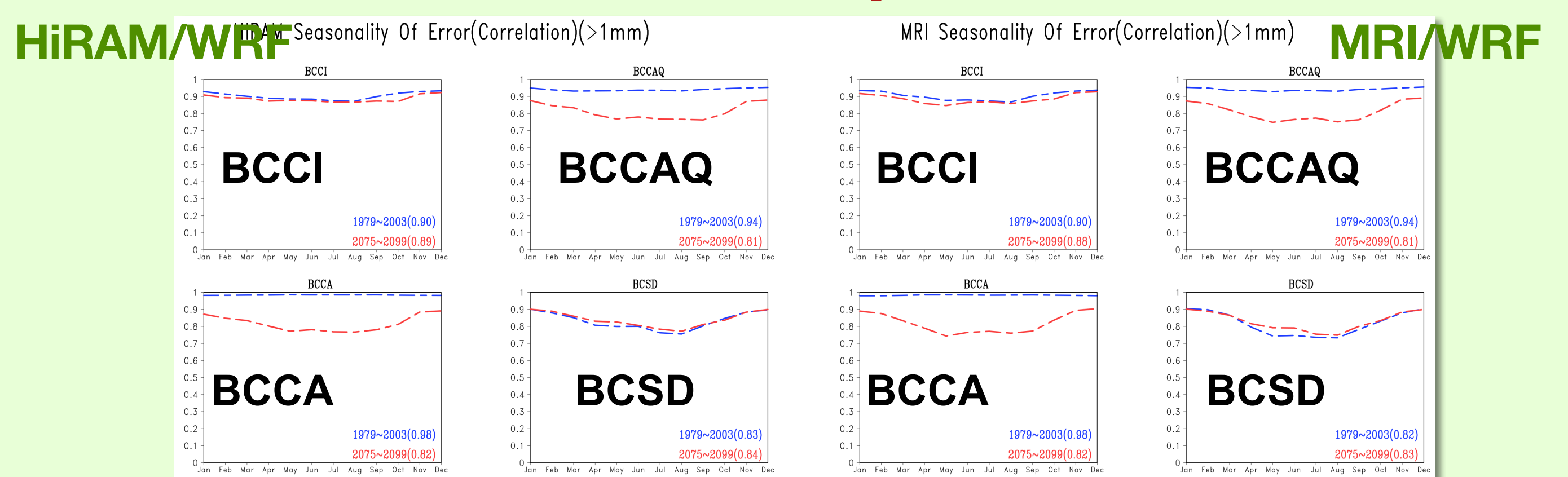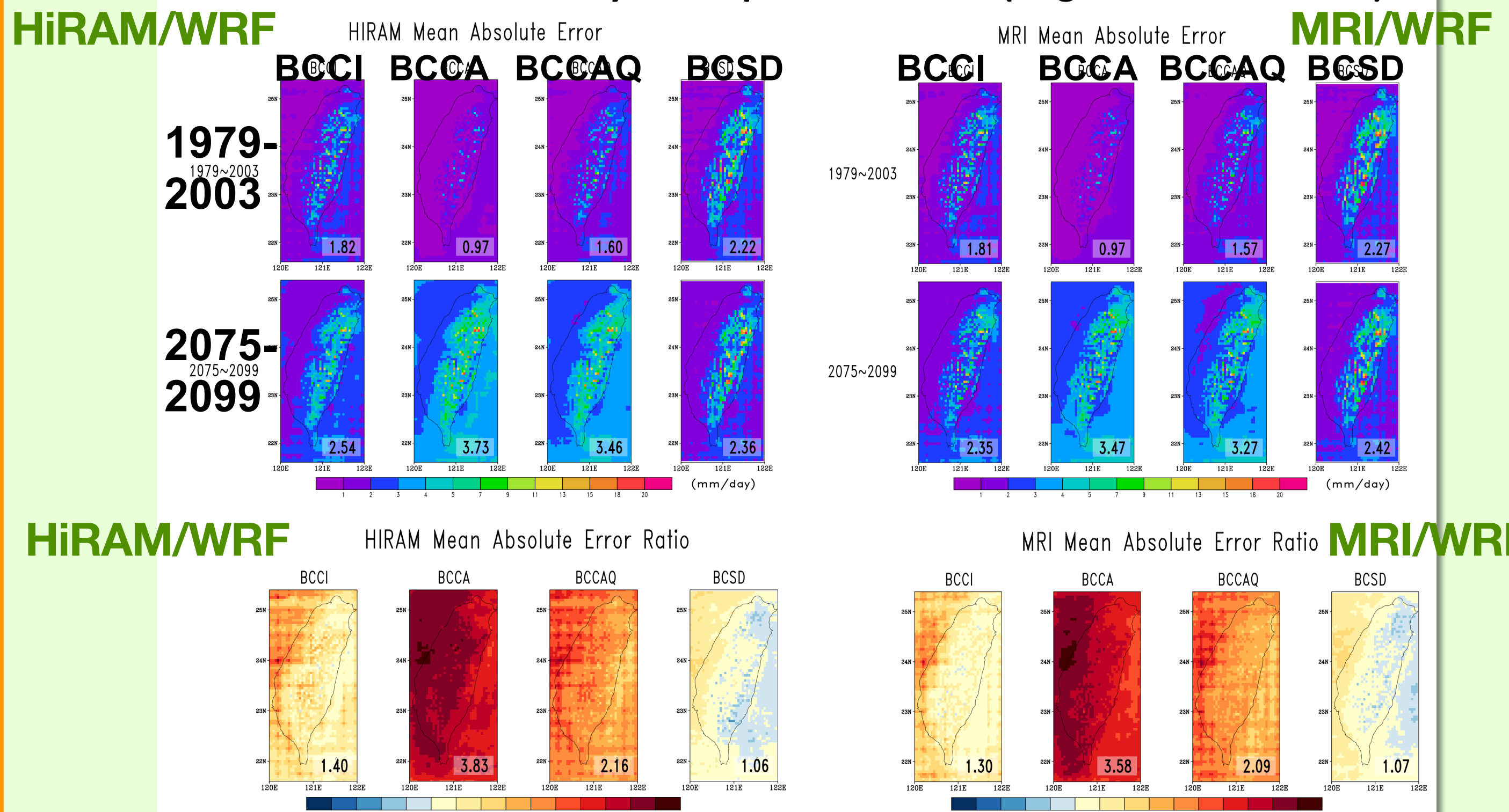**Present Climate 1979-2003 (Training)**   **RCP 8.5 2075-2099 (Projection)**

MRI/WRF 1979-2003: BCCA: 0.983, BCCAQ: 0.941, BCCI:0.903, BCSD:0.815
MRI/WRF 2075-2099: BCCA: 0.815, BCCAQ: 0.807, BCCI:0.884, BCSD:0.827
HiRAM/WRF 1979-2003: BCCA: 0.980, BCCAQ: 0.940, BCCI:0.900, BCSD:0.825
HiRAM/WRF 2075-2099: BCCA: 0.809 BCCAQ: 0.802, BCCI:0.883, BCSD:0.832

Seasonality

HiRAM/WRF — BCCI, BCCAQ, BCCA, BCSD
MRI/WRF — BCCI, BCCAQ, BCCA, BCSD

Statistical vs. Dynamical Downscaling

Statistical Models Perform Well

WRF-MRI, BCSD, BCCA, SPA-MRI-m00, BCCI, BCCAQ

Mean Absolute Error of Daily Rainfall

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

HiRAM/WRF — BCCI, BCCA, BCCAQ, BCSD
MRI/WRF — BCCI, BCCA, BCCAQ, BCSD

1979-2003: 1.82, 0.97, 1.60, 2.22 | 1.61, 0.97, 1.57, 2.27
2075-2099: 2.54, 3.73, 3.46, 2.36 | 2.35, 3.47, 3.27, 2.42

HiRAM/WRF — BCCI, BCCA, BCCAQ, BCSD
MRI/ — BCCI, BCCA, BCCAQ, BCSD

HIRAM Mean Absolute Error Ratio: 1.40, 3.83, 2.16, 1.06
MRI Mean Absolute Error Ratio: 1.30, 3.58, 2.09, 1.07

Statistical Models Fail

WRF-MRI, BCSD, BCCA, SPA-MRI-m00, BCCI, BCCAQ

Temporal Correlation Daily Rainfall at Grids

HiRAM/WRF — BCCI, BCCA, BCCAQ, BCSD
MRI/W — BCCI, BCCA, BCCAQ, BCSD

1979-2003: 0.97, 0.99, 0.97, 0.96 | 0.96, 0.99, 0.97, 0.95
2075-2099: 0.91, 0.85, 0.86, 0.95 | 0.92, 0.86, 0.88, 0.94

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

Legend: BCCA, BCCAQ, BCCI, BCSD

Months: 1月 2月 3月 4月 5月 6月 7月 8月 9月 10月 11月 12月 年