High-Resolution Hybrid Downscaling Reveals Drizzle's Role in Compound Moist Heatwave-Precipitation Events

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INTRODUCTION

– Moist heatwaves increasingly threaten tropical low-lying regions such as Southeast Asia, where high population density and vulnerability amplify impacts.
– While extreme heat and humidity are well studied, **compound moist heatwaves** and their interactions with precipitation, especially **very light rainfall (drizzle)**, remain underexplored.
– Moreover, **coarse-resolution GCMs** are known to inadequately represent light-precipitation processes and **exhibit systematic biases**, limiting reliable assessments of compound moist heatwave dynamics.

We aim to address: Do drizzle and extreme precipitation differentially modulate compound moist heatwave characteristics, and can high-resolution downscaling better capture these processes across past and future climates?

Take-home message: Fine-scale downscaling is essential for capturing the frequency of drizzle-driven moisture persistence that modulates compound moist heatwaves.

REGION OF STUDY & APPROACHES

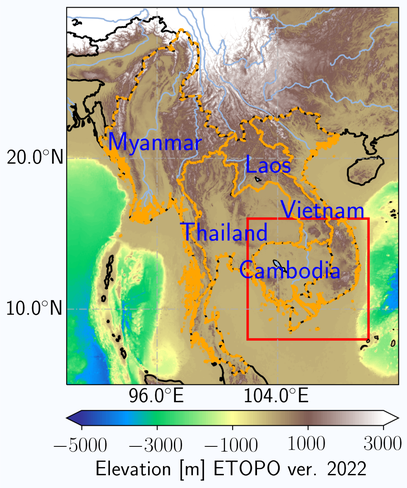

Figure: Topography of the Greater Mekong Subregion (orange dashed boundary). The Region of Interest (ROI) spans **102°–110°**E and **8°–16°**N.

Input Data
Type: 17 GCMs-CMIP6, observation (MSWX-GloH2O)
Variable(s): maximum air temperature, relative humidity, precipitation
Historical period: 1981−2014; Projections: SSP1-2.6 & SSP5-8.5: 2015−2100

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Statistical Downscaling technique: BCCAQ
Bias **C**orrection **C**onstructed **A**nalogues with **Q**uantile mapping reordering

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Validation, projections & uncertainties
+ Multi-comparisons spatial and temporal against OBS, RCMs;
+ Evaluation metrics: NRMSE, KGE, IOA, CORR;
+ Uncertainties

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Output: BCCAQ dataset 0.1° grid, daily

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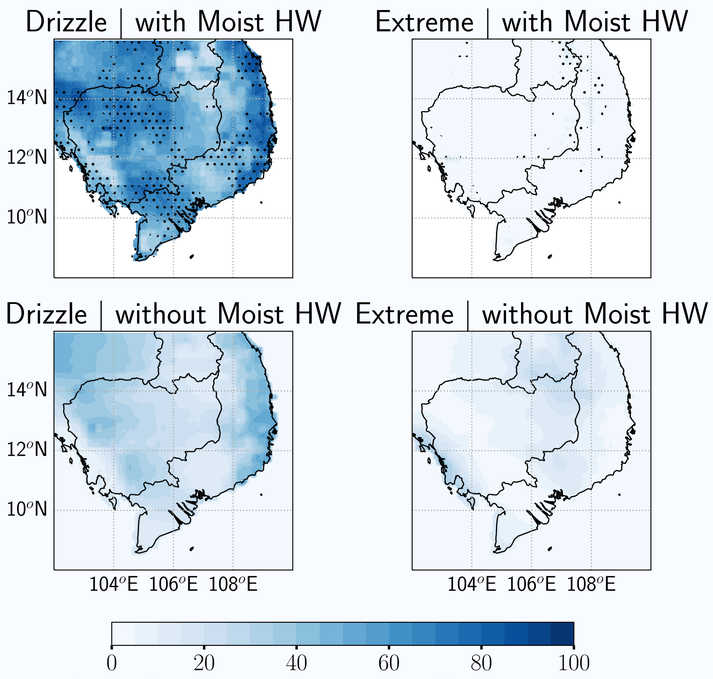
Compound Moist Heatwaves and Multiple-type Precipitation (this poster)
○ via: frequency, duration and intensity

Figure: Approaches

• **Moist Heatwave (MHW)** A heatwave is defined as a period of at least three consecutive days during which daily maximum air temperature exceeds its local 90th percentile of the JJASO climatology (1981–2014). A **MHW** is further identified when relative humidity (RH) is $\geq$ 66%.

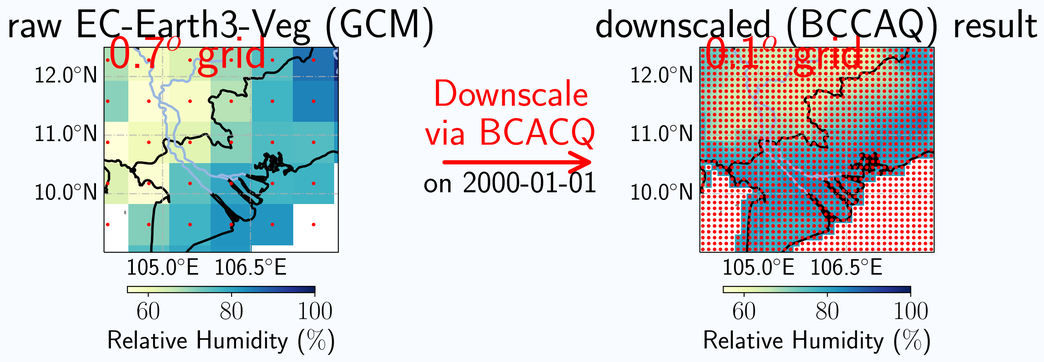
•**Compound Moist Heatwave–Precipitation (CMHWP)**
+ A CMHWP occurs when a MHW temporally overlaps with a precipitation-type event within a predefined window (±7 days). **Drizzle** and **Extreme** precipitation are defined as daily precipitation below the 10th percentile and above the 90th percentile of the JJASO climatology (1981–2014), respectively.

+To avoid redundancy, each precipitation event is matched to the nearest MHW in time; when multiple matches occur, only the **longest-duration drizzle** or **strongest extreme precipitation** event is retained. Compound events are treated as **sequential processes**, allowing precipitation to occur during or shortly after a MHW.

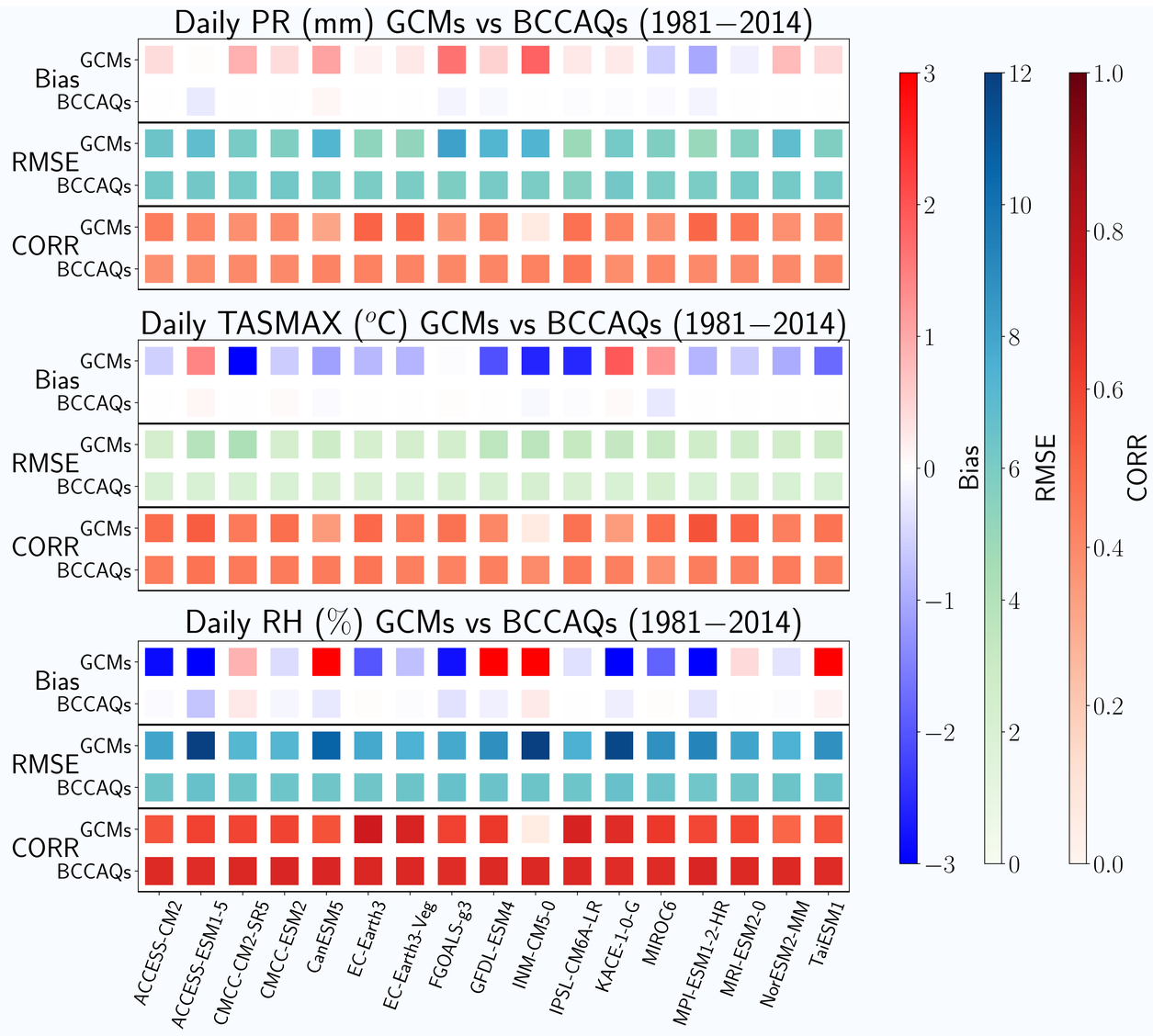


How does the occurrence frequency of drizzle and extreme precipitation differ during Moist HW compared to non-Moist HW days over ROI?

○ Downscaling concepts (schematic illustration)



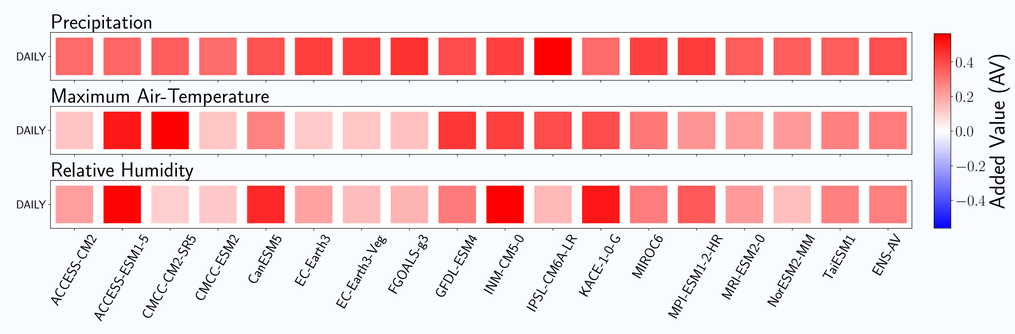
VALIDATIONS & ADDED VALUES of BCCAQs



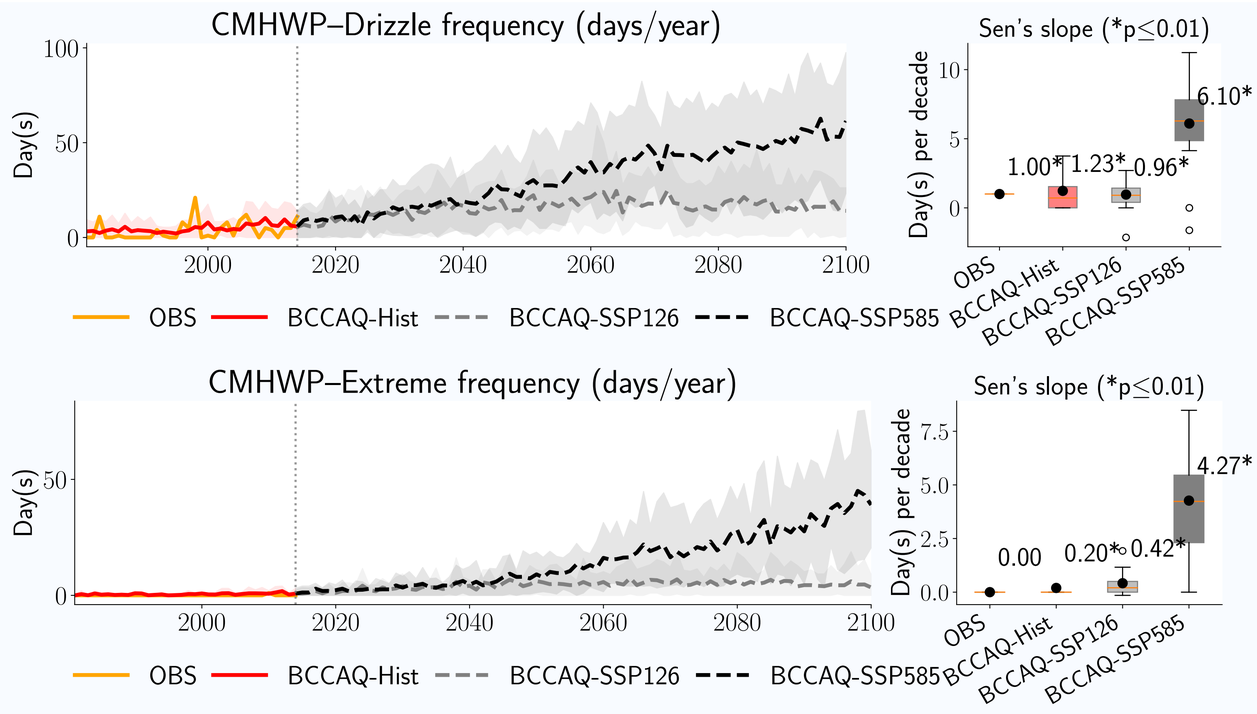
Does downscaling (BCCAQs) add value compared to parent GCMs ?
With X being climate statistics, Added Value (AV) is recalled by Alessandro Dosio et al. (2013a)

$$AV = \frac{\overline{\Delta^2_{GCM}} - \overline{\Delta^2_{DS}}}{\Delta^2_{GCM} + \Delta^2_{DS}}$$

where $\Delta = X - X_{OBS}$



Compound Moist HW-Precipitation Events Projections



• CMHWP–Drizzle exhibits the most rapid increase under SSP585 (**+6.1** days decade^{-1}), substantially exceeding both SSP126 and historical simulations, whereas observed records indicate only marginal changes. In contrast, CMHWP–Extreme events intensify primarily under SSP585 (**+4.3** days decade^{-1}), while remaining infrequent with negligible trends under SSP126 and in observations.
• Under SSP585, enhanced warming markedly increases atmospheric moisture, favoring the occurrence of moderate but persistent moist (wet)–humid conditions over true extremes, which remain constrained by large-scale dynamical processes.

• Future work will explicitly address and quantify the associated uncertainties.

Acknowledgement & References

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