P-72

地球・宇宙

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

TECHNOLOGY SHOWCASE



## ■ はじめに

Moist heatwaves (MHWs) pose a growing threat to low-lying tropical regions, particularly across the Indian subcontinent and Southeast Asia (SEA), where high population density and socio-environmental vulnerability amplify their impacts. While the devastating effects of extreme heat and humidity have been well documented, compound moist heatwaves (CMHWs) — events co-occurring with other climatic drivers — remain less well quantified. Most previous studies have focused on heavy precipitation extremes but often overlooked the tail characteristics of these events, especially very light precipitation (drizzle), can modulate boundary layer moisture, which can sustain high humidity and prolong CMHW duration. This study investigates the contribution of drizzle as well as extreme precipitation to CMHWs under both historical (1981-2014) and future (2015-2100, SSP1-2.6 and SSP5-8.5) climate scenarios by downscaling CMIP6 simulations to a high spatial resolution (9 km) for improved local assessments. Model performance evaluation based on frequency and intensity metrics highlights a clear superiority of the hybrid-downscaled product (0.81 and 0.88 for drizzle and extreme, respectively) over NASA NEX-GDDP (0.63 and 0.79) and raw GCM outputs (0.66 and 0.74). These results emphasize the critical role of fine-scale downscaling in accurately capturing persistent light-precipitation processes that shape the intensity and persistence of CMHWs.

## ■ 活動内容

1. The downscaling was conducted using the Bias Correction Constructed Analogues with Quantile Mapping Reordering (BCCAQ) method. BCCAQ integrates two complementary techniques: (1) the Constructed Analogues reconstructs high-resolution fields by selecting observed analog days that best match large-scale model patterns, and (2) Quantile Mapping Reordering, which adjusts the statistical distribution of model outputs to match observations while preserving temporal sequencing. This hybrid approach corrects both mean and distributional biases, maintains temporal structure, and enhances the local-scale representation of temperature and precipitation extremes. Validation against the MSWX baseline showed reduced errors in daily mean and extreme values for maximum temperature, relative humidity, and precipitation. A Moist Heatwave (MHW) event was defined as a period when daily maximum temperature exceeds the 90th percentile of the reference period (1981-2014, May-October) and relative humidity is at least 66%, lasting for a minimum of three consecutive days and up to a maximum of six days per event.

2. Compound Moist Heatwave-Precipitation (CMHWP) events were identified when a MHW was followed by drizzle ($\leq$ 2.9 mm day$^{-1}$) or extreme precipitation ($\geq$ 8.5 mm day$^{-1}$) within 4 days (based on composite analysis on observation). Four diagnostic metrics were computed:

- Frequency (F) = (number of CMHWP events per year), representing occurrence rate;
- Average Duration (D) = $\Sigma$(duration of each event)/N, indicating persistence;
- Longest Duration ($D_{max}$) = maximum duration among all events, reflecting extremity.
- Intensity (I) = $\Sigma(T_{max} - T_{90})$/duration, describing cumulative temperature excess above the 90$^{th}$ percentile threshold.

## ■ 関連情報等(特許関係、施設)

This research is supported by the Ministry of Education, Culture, Sports, Science and Technology, Japan, under the Japanese Government MEXT: Monbukagakusho Scholarship (Interdisciplinary Resilience Engineering Program Powered by Project-Based Learning: 19011, 22016).

代表発表者 NGUYEN NGOC KIM HONG
(グエン ノ キム ホン)
所 属 Graduate School of Science and Technology
University of Tsukuba
問合せ先 〒305-0006 茨城県つくば市天王台 2 丁目 1 番地
筑波大学一の矢宿舎 20-310
TEL:080-3308-2371
hongnguyen.ngock2@gmail.com

■キーワード: (1) Downscaled
(2) Compound Moist Heatwave
(3) Climate Projection

■共同研究者: 大樂 浩司
(University of Tsukuba)