

Fog Suppresses Microclimate Spatiotemporal Variability by Weakening Land–Atmosphere Interactions

Yi-Shin Jang 張譯心¹, Min-Hui Lo 羅敏輝¹, Yen-Jen Lai 賴彥任²

¹ Department of Atmospheric Sciences at National Taiwan University

² Experimental Forest, National Taiwan University; School of Forestry & Resources Conservation,
National Taiwan University

Abstract

Land type is the critical driver of the surface energy budget and determine the partition of heat fluxes, thereby defining the core characteristics of land-atmosphere interactions. The spatial heterogeneity of land use creates microclimate spatial variation and enhance local circulation. Cloud and fog dynamic strongly modulate the downward radiation that drives land–atmosphere interactions. These variations play a crucial role in shaping the spatial heterogeneity of hydro-climatological cycles. However, limitation in the temporal continuity and spatial resolution of satellite and radiosonde observations hinder our ability to capture the diurnal evolution of near-surface atmospheric vertical structures. To address this challenge, we investigate the influence of fog events on the spatiotemporal variation of microclimate across different land types using paired in-situ meteorological observation and 40m tethered balloon. During fog events that simultaneously affect both a forest site and an adjacent open field, the near-surface air temperature difference between two land types decreases significantly from $4.58\pm 2.49^{\circ}\text{C}$ to $1.51\pm 1.09^{\circ}\text{C}$ at noon, and from $-3.57\pm 2.03^{\circ}\text{C}$ to $-1.20\pm 3.46^{\circ}\text{C}$ at 7:00 AM, respectively. Vertical temperature profiles further reveal that fog stabilized the near-surface atmosphere, reducing the vertical temperature gradient at noon from $-0.56\pm 0.12^{\circ}\text{C}/\text{m}$ under non-foggy conditions to $-0.24\pm 0.03^{\circ}\text{C}/\text{m}$ under foggy events. Additionally, cloud and fog temporarily weaken land–atmosphere interactions by reducing incoming shortwave radiation, thereby suppressing surface heat flux and forming a stable and vertically uniform atmospheric structure. This process also diminishes the spatial heterogeneity of near-surface microclimate. These findings highlight the pivotal role of fog in modulating the spatiotemporal variability of microclimate and underscore its broader implications for understanding land–atmosphere coupling under shifting land use and climate. As fog frequency declines under future climate scenarios, regions that were once frequently fog-covered may become more vulnerable to microclimatic impacts driven by land-use change.

Keyword: Montane cloud forest, Land-atmosphere interactions, Microclimate