8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-127

Effects of orographically induced low-level moisture convergence and inversion strength on upslope fog: a case study at Xitou

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Montane cloud forest (MCF) is characterized by forest which is frequently immersed in clouds or fog so that the interception of cloud/fog water provides extra hydrological input to this ecosystem. Previous studies suggest that under global warming scenario, the rise of cloud base height could leads to an upward shift of MCF. This impact could lead to the shrinking and fragmentation of MCF over complex topography such as Taiwan, a subtropical island with more than 200 peaks and the elevations ranging from sea level to nearly 4,000 m. Previous studies of MCF in Taiwan is merely focusing on the dynamic and thermodynamic processes of the fog formation. In this study we examine the effects of orographically induced moisture convergence and the processes of fog formation at Xitou valley of Taiwan by ceilometer observation and idealized large eddy simulations. This is the first attempt to understand the local circulation associated with fog at Xitou using a high-resolution cloud-resolving model. Observation analysis shows that the ceilometer is not only reliable to detect fog occurrence but also provides more information about low-level cloud base evolutions. In a fog case on Jan. 7th, 2016, the low-level cloud base lowering is observed before ground fog formation, which is also associated with the valley winds at Xitou valley as previous studies mentioned. To understand the processes of the moisture transport associated with the fog formation, idealized simulations using high-resolution vector vorticity equation cloud-resolving model (VVM) with realistic land surface processes are performed to evaluate the local circulation associated with the fog development. The results indicate that both the upslope winds and the turbulent eddies at the edge of the upslope winds are primary local processes to moisten the boundary layer in the valley which leads to fog formation at Xitou. Sensitivity experiments on inversion strengths show that local fog duration is also controlled by synoptic inversion strength. The results show that the effects of orographically induced low-level moisture convergence are the essential processes to supply moisture in the Xitou valley, and the capping inversion helps the ground fog formation by limiting the development of convections and preserve moisture in the valley. With stronger capping inversion above Xitou valley, the moisture is trapped in the valley, and the fog duration is consequently longer.