Influence of CCN on Summer Afternoon Thunderstorms in Taiwan

Chang, Yu-Hung[1], Wei-Ting Chen[1], Chien-Ming Wu[1]

[1] Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan

This study investigates how increasing cloud condensation nuclei (CCN) affects summer afternoon thunderstorms (TS_A) in Taiwan using the Vector Vorticity equation cloud-resolving Model (VVM) with interactive land surface model (Wu et al. 2019) and the Predicted Particle Properties (P3) microphysics scheme (Morrison et al. 2015). We select nine TS_A cases from 2006 to 2010 under southwesterly (SW) or weak synoptic (WS) conditions based on the Taiwan Atmospheric Events Database (TAD, Su et al. 2018) as well as the Central Weather Bureau (CWB) surface rain gauge observations and Tropical Rainfall Measuring Mission (TRMM) 3B42 satellite rainfall estimates. Semi-realistic large-eddy simulations (LES) for the nine selected cases are carried out over the high-resolution complex terrain of the Taiwan Island, driven by the simplified observational soundings. High convective available potential energy ($> 900 J/kg$) and column water vapor (> 43mm) are features that these soundings share, while the depth of southwesterly varies. In the control simulations, the CCN number mixing ratio is fixed at $3 \times 10^7 \#/kg$ in the entire domain to represent the clean scenario, while in the experimental (polluted) simulations the CCN number mixing ratio is increased to $3 \times 10^{10} \#/kg$. The composite of the simulated results reveals a precipitation hotspot around Alishan Mountain Range (AMR), which corresponds with observational study by Lin et al. (2012). The CCN delay the initiation of TS_A, while the other characteristics related to precipitation, such as duration of rain and total precipitation, are highly variable. Three types of TS_A precipitation response to increasing CCN are distinguished over the AMR region: low precipitation, strengthened precipitation peak, and time shift in precipitation peak. The first type is characterized as peak precipitation intensity lower than $2\,mm/hr$. The second type shows that peak precipitation intensity in polluted scenario is at least $1\,mm/hr$ higher than that in clean scenario. There is no significant difference in peak precipitation intensity between the two scenarios in the last type, but the timing delays in polluted scenario. These different responses are likely controlled by initial atmospheric conditions and local circulation developed over the complex topography of the AMR region. The changes in precipitation intensity spectra and the size distribution of convective cloud objects will also be investigated.

Key Words:

cloud condensation nuclei, Taiwan topography, afternoon thunderstorm, large-eddy simulation

References:

Lin, P.-F., P.-L. Chang, B. J.-D. Jou, J. W. Wilson, and R. D. Roberts. 2012. Warm Season Afternoon Thunderstorm Characteristics under Weak Synoptic-Scale Forcing over Taiwan Island. *Weather and Forecasting* 26(1): 44-60.

Morrison, H., and J. A. Milbrandt. 2015. Parameterization of Cloud Microphysics Based on the Prediction of Bulk Ice Particle Properties. Part I: Scheme Description and Idealized Tests. *Journal of the Atmospheric Sciences* 72(1): 287-311.

Su, S.-H., J.-L. Chu, T.-S. Yo, and L.-Y. Lin. 2018. Identification of Synoptic Weather Types over Taiwan Area with Multiple Classifiers. *Atmospheric Science Letters* 19(12).

Wu, C.-M., H.-C. Lin, F.-Y. Cheng, and M.-H. Chien. 2019. Implementation of the Land Surface Processes into a Vector Vorticity Equation Model (VVM) to Study its Impact on Afternoon Thunderstorms over Complex Topography in Taiwan. *Asia-Pacific Journal of Atmospheric Sciences*.