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Verification of fugitive emission of aeolian river dust and impact on air quality in central western Taiwan by observed evidence and simulation

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ABSTRACT

Taiwan's rivers dry during the winter, exposing large areas of river bed and leading to airborne aeolian river dust. This study used PM_{10} and windspeed data taken from monitoring stations local to the Zhuoshui River (the river with the largest exposed area in Taiwan) to investigate the relationship between airborne river dust and air quality, and subsequently to estimate river dust emissions. During river dust events, PM_{10} concentrations were significantly and positively correlated with wind speeds exceeding 5 m/s (the critical wind speed). FPG Lunbei station, located downwind (south of the river) and the closest station to the river, recorded an average hourly PM_{10} concentration of 189 ± 193 μg/m^3 an average correlation coefficient (*r*) of 0.94 between hourly PM_{10} concentration and average hourly wind speed, an average annual dust occurrence rate of 15%, and a maximum PM_{10} concentration exceeding 1000 μg/m^3. $PM_{2.5}$ increased with PM_{10}, albeit at a disproportional rate. When hourly PM_{10} concentration exceeded 200 μg/m^3, most of the particulates in the dust were coarse particulates ($PM_{2.5–10}$). An hourly $PM_{2.5}/PM_{10}$ ratio of <20% was used to determine whether air quality is affected by river dust. As the PM_{10} concentration increases, the $PM_{2.5}/PM_{10}$ ratio decreases. It was concluded that soil moisture and surface roughness must be added into the estimations for producing simulated data. With these added, simulated results were highly consistent with observed hourly PM_{10} concentrations, with a Pearson correlation coefficient of 0.82. The simulations of hourly PM_{10} concentration were highly accurate and indicated that river dust from the Zhuoshui River contributed to substantial increases in downwind PM_{10} concentrations. December was the worst single month, accounting for 28.0% of PM_{10} dust created by the Zhuoshui River in the entire year. Air quality was, however, severely reduced just south of the Zhuoshui River throughout the fall and winter.

1. Introduction

Windblown transport of dust is a common physical phenomenon across the world. When wind blows on a surface, particulate matter (PM) on that surface may be moved in one of three different ways. Big particles start to roll (creep). Smaller particles describe ballistic-like trajectories as they are lifted off and fall back to the surface, triggering a chain reaction by colliding with other particles, a phenomenon known as saltation. Still smaller particles are entrained by the wind, and can be transported over large distances (Ali, 2018; Giudice and Preziosi, 2020; Suresh et al., 2021).

Large scale windblown transport of dust from Africa's Sahara Desert to southern Europe and South America and from the Gobi Desert to East Asia and North America is able to affect the global radiation budget, air quality, and ecosystems via the delivery of nutrients (Ginoux et al., 2012; Kok et al., 2012; Prospero et al., 2014; Cadavid Restrepo et al., 2017; Yang et al., 2019; Baldo et al., 2020; Xia et al., 2020; Bai et al., 2021). Smaller dust sources such as agricultural lands (Chung et al., 2013; Oyebanji et al., 2021), arid and semi-arid areas (Choi et al., 2006; Jayaratne et al., 2011; Lu et al., 2013; Rashki et al., 2017; Gholami et al.,

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