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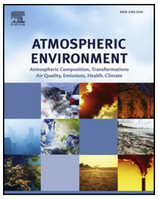

Impact of river-dust events on air quality of western Taiwan during winter monsoon: Observed evidence and model simulation

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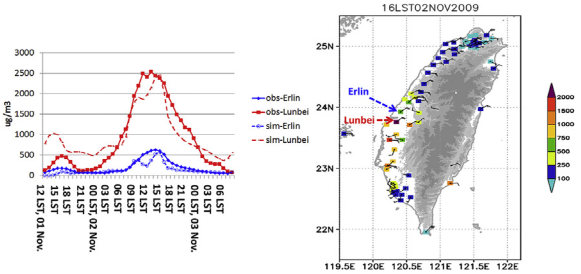
GRAPHICAL ABSTRACT

Temporal variation of observed and simulated PM_{10} concentration at Erlin (EL) and Lunbei (LB) from 12 LST, 1 Nov., to 8 LST, 3 Nov., 2009 (Left panel). Observed PM_{10} concentration and wind recorded in Taiwan (right panel) at 08 UTC (16 LST) 02 Nov., 2009.



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ABSTRACT

River dust has severe impact on air quality in western Taiwan under prevailing strong northeasterly winds during passage of cold fronts. Data showed that river dust in western Taiwan from November to April came mainly from Choshui River (CS). The difference in mean seasonal concentration of river dust upstream of CS at station Erlin (EL) and downstream at station Lunbei (LB) could be as high as 14.2 μg/m^3 during northeasterly monsoon from 1994 to 2015. A major river-dust event with unprecedented PM_{10} concentration occurring in western Taiwan on 2 November, 2009 was examined to understand further the mechanism behind its occurrence and impact on air quality. Weather conditions of 1–2 November, 2009 showed a clear pressure gradient in a strong baroclinic environment associated with a prevailing strong continental outflow (northeasterly, ≥ 12 m/s) that lasted more than 30 h over the coastal area of China. On 2 November, 2009, the peak concentration of PM_{10} concentration was 600 μg/m^{3}at EL but exceeded 2500 μg/m^3 at LB. While wind speeds of these two stations were comparable, the PM_{10} concentration at LB was more than four times that at EL due to dust blown up from CS riverbed. These findings could be reasonably captured by the WRF-Chem model. Simulation results also indicated that the depth of this strong northerly wind (> 10 m/s) was below 1000 m and its intensity increased significantly after 0 LST on 2 November, 2009. Strong wind did not favor vertical diffusion of river dust, thus trapping it below 200 m in height and causing severe dust concentration at near-surface level. Besides high wind speed, dry atmospheric and surface drought conditions also contributed to increase river dust suspension in the air. The results and methods obtained in this study can be applied to other regions of similar environment and with comparable relief.

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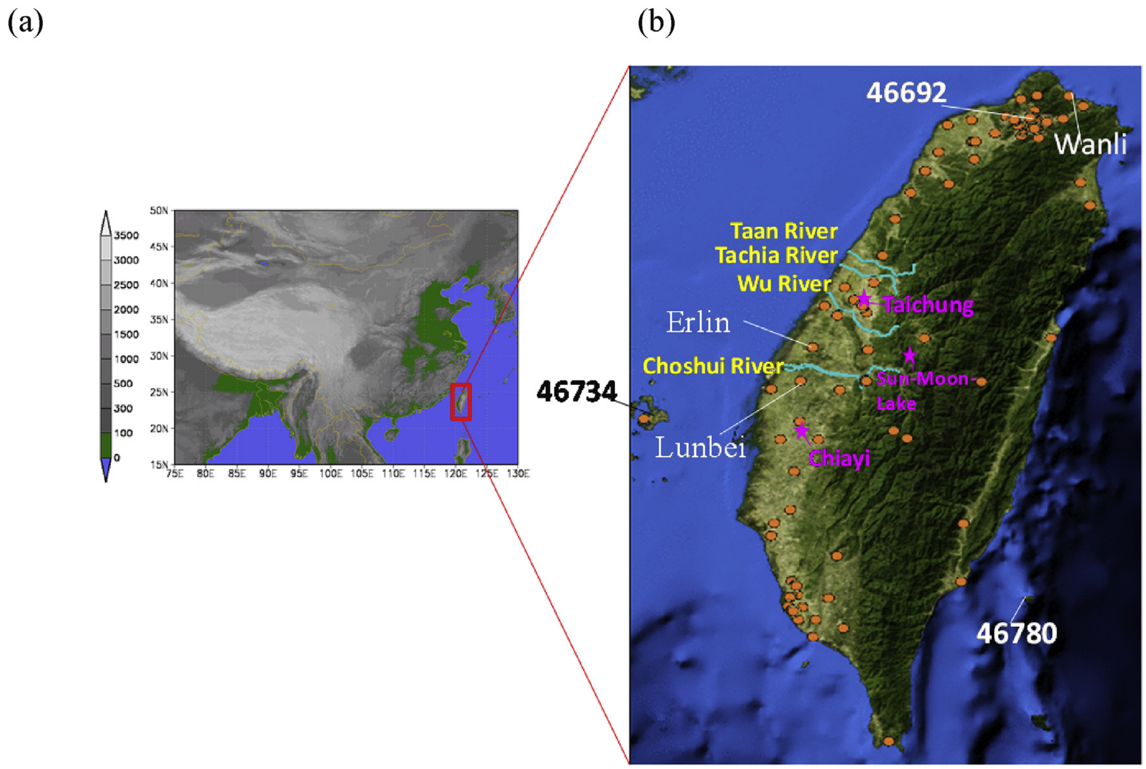

Fig. 1. (a) Location of Taiwan and surrounding countries in East Asia (b) Location of air quality monitoring stations of Environmental Protection Administration (EPA), Taiwan, sounding stations (46692, 46734 and 46780), Sun moon lake, Chiayi and Taichung rain gage stations of Central Weather Bureau and major rivers (Taan, Tachia, Wu and Choshui) in western Taiwan.

1. Introduction

Particulate Matters (PM) constitute one of the major air quality concerns in many places of the world. Their sources could be long-range transport or local emission of natural and anthropogenic pollutants. Aeolian dust is a common phenomenon caused by strong winds under certain drought atmospheric conditions such as monsoon, foehn winds and even typhoon circulations. Especially, the sources of the dust emission are not from the well-known area such as the Gobi or the Sahel deserts. For examples, there are number of researchers demonstrated aeolian dust around Alps, New Zealand (e.g. McGowan et al., 1996; Larsen et al., 2014), in the southern High Plains of the United States (e.g. Lee et al., 1993, 1994), Dead Sea valley (Kishcha et al., 2017), Victoria Valley, Antarctica (Speirs et al., 2008) and Athabasca River Valley, Canadian Rocky Mountains (Hugenholtz and Wolfe, 2010). Under the climate change, drought risk is increasing and the possibility of aeolian dust due to bareland of river or lake will increase in the future and hence are attracting more and more attentions on this issue.

During winter monsoon in East Asia, northeasterly wind prevails from November to April under strong continental outflow. Taiwan is located in the southeast of mainland China. Long-range transport of Asian dust together with air pollutants is often brought by the strongly northeasterly wind to downstream Taiwan (Lin et al., 2004, 2005, 2007, 2012), mainly in late winter and during spring from February to April (Wang et al., 2000, Murayama et al., 2001, Lin et al., 2004, 2005), depending on the atmospheric conditions of the lower boundary layer over northern China. Winter monsoon is commonly recognized as the major drought season in the western plain of Taiwan. Dry atmospheric condition and strong wind can easily blow up dust from riverbeds, thus affecting both local visibility and air quality.

The impact of frequent occurrence of river-dust events on the air quality of Taiwan has attracted the attention of the local Environmental Protection Administration (Environmental Protection Administration, 2009) and many researchers (Kuo et al., 2010; Lin et al., 2007, 2008; Hsu et al., 2016a; b; Lin et al., 2016; Chuang et al., 2016). Estimation of the EPA showed nine river-dust events per year over western Taiwan between 1994 and 2007 (Environmental Protection Administration, 2009). Kuo et al. (2010) pointed out that river dust in central Taiwan came mainly from the bare soil formed at downstream of CS during drought season. Furthermore, farmers turning over the bare soil of riverbed for agricultural purposes also destroyed the surface layer and aggravated the suspension of river dust under strong wind during winter monsoon.

In western Taiwan, there are four major rivers, Taan (TA), Tachia (TC), Wu and Choshui (CS) (Fig. 1). In general, land use/cover of a river includes the water body, vegetation, and wet/dry bareland. In the bareland of dry riverbeds in western Taiwan, the diameter of sand varies widely, being 135, 84, 46 and 1.9 mm at TA, TC, Wu and CS, respectively (Environmental Protection Administration, 2009). There also exist significant differences in mass median diameter of sand in these four rivers. Consequently, the chances for dust suspension to be generated in these rivers are not comparable. TA rarely has river-dust suspension because of its narrow riverbed and largest dust particle sizes. Furthermore, TA is located in a hill county whose relief is also adverse to dust suspension generation. CS, with its widest riverbed of maximum width approximating 3 km, lowest water level during the drought season from November to April, and smallest mass median diameter of 1.9 mm, contributes the majority of suspended river dust (Environmental Protection Administration, 2009; Kuo et al., 2010, Lin et al., 2007, 2008, 2016). Satellite images from 2005 to 2010 showed 30–60% of land cover of CS being bareland (Lin et al., 2016). Kuo et al. (2010) also reported higher dust concentration in CS than in the other three rivers, ranging from five-to seven-fold.

Numerous efforts have been devoted to establishing the emission inventory of river dust (Lin et al., 2008; Environmental Protection Administration, 2009; Lin and Yeh, 2007; Lin and Lin, 2012; Lin et al., 2016), analyzing the composition of river dust (Fang et al., 2009; Kuo et al., 2010; Lin et al., 2009; Hsu et al. 2016a, 2016b) and examining