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Simulating the impact of East Asia Dust Event during the Spring Season on Taiwan: A Testing of the New Windblown Dust Module in CMAQ

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1. INTRODUCTION

Mineral dust has been a great concern towards human beings as it carried huge impact on the earth's system. It brings important implication for air quality (De Longueville *et al.*,2010), reduced the visibility (Seinfeld *et al*., 2004), change the earth's radiation budget (Miller et al., 2006), hydrological process (Zhao *etal*, 2011) and atmospheric chemistry (Dong *et al*., 2016 and Wang *et al*., 2012). Asian dust storm events was mostly significant or common during the late winter and spring including March, April and May (Lin et al., 2007; Liu & Shiu, 2001). It have been a great and popular issue over the northern China, Mongolia and Central Asia during the high wind conditions (Shao & Dong, 2006)(Lin et al., 2007; Liu & Shiu, 2001). Overall, the sources of EAS can be originated from the deserts from China and Mongolia such as Taklamakan and Gobi deserts.

Numerous research works has been done to analysis the dust storm event by monitoring and modeling over East Asia (Chen et al., 2017; Lin et al., 2007; Wang et al., 2018; Wang et al., 2011). The simulation of dust emission in East Asia is more complicate compared to the other region due to the complex meteorology condition, topography and land cover. In the recent decade, several studies related to the dust emission has been done by applied air quality model including CMAQ (Dong et al., 2016; Foroutan et al., 2017; Huang et al., 2013; Q. Wang et al., 2018), WRF-Dust (Bian et al., 2011), WRF-Chem(Chen et al., 2013; Nabavi, Haimberger, & Samimi, 2017) and RegCM4-Dust(Sun, Pan, & Liu, 2012). The present study intends to evaluate the performance of CMAQ model in projecting the particulate matter, with the implementation of new dust model modulated by Foroutan et al. (2017).

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2. METHODOLOGY

The present study used CMAQ version 5.2.1 to simulate the particulate matter over the Taiwan region during the month of April 2018. The model was run based on a one-way nesting technique in which NCEP Global Forecast System (GFS) and Taiwan Emission Database (TEDS9.0) were used as meteorological and emission inventory input for the modelling system respectively. Simulation over East Asia region was carried out with a coarse domain of 81km, and then downscaled towards Taiwan region with finer resolution including 27km, 9km and 3km (Fig. 1). Gas phase chemistry is represented as Carbon Bond V (CB05) chemical mechanism with the aerosol module (AERO5).

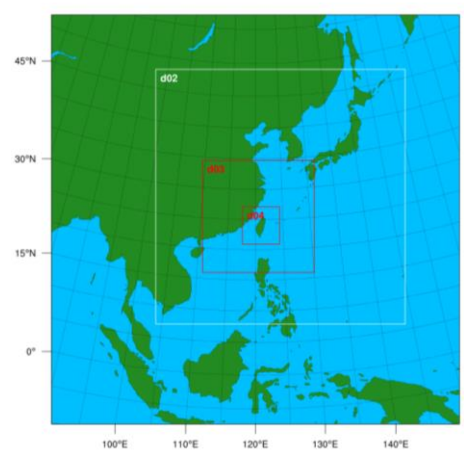


Fig. 1. Modeling domain configuration.

The present study intends to utilize the new wind-blown dust scheme from CMAQ(v5.2.1). A number of environmental variables including wind speed, soil texture, land use type, vegetation cover and soil moisture determined the process of wind-blown dust emission (Dong et al. 2016).

CMAQ used the dust emission scheme developed by Tong et al. (2016), where Foroutan et al. (2017) modulated the scheme again based on improvement of the variables mentioned. Table 1 showed the three simulation scenarios namely CMAQ_Nodust, CMAQ_Default and CMAQ_Revised and its corresponding descriptions.

Table. 1. Brief description of modeling scenarios.

Scenarios	Descriptions
CMAQ_Nodust	Without in-line calculation of dust
CMAQ_Default	With default wind-blown dust emission scheme
CMAQ_Revised	Revised the soil moisture fraction in dust scheme

3. RESULT AND DISCUSSION

Fig. 2 showed the time series of the observed PM_{10} and $PM_{2.5}$ for the six ground observations sites from Environmental Protection Agency (EPA) in Taiwan region, namely Wanli, Pinzhen, Shinzhu, Xitun Sinyin and Zhuoyin during April 2018. The location of the ground observation sites was shown in Fig. 3. In Wanli station, the dust event was found, where the high concentration of PM_{10} was found as compared to $PM_{2.5}$ during 7th of April, with the highest concentration can reach up to 240µgm^{-3}. Besides that, the second dust event was observed on 16th of April with PM_{10} around 200µgm^{-3}. Similar situation happened in the other cities but the peak concentration was not obvious, probably because the dust was not able to transport further due to the long distance between the north and southern part of Taiwan.

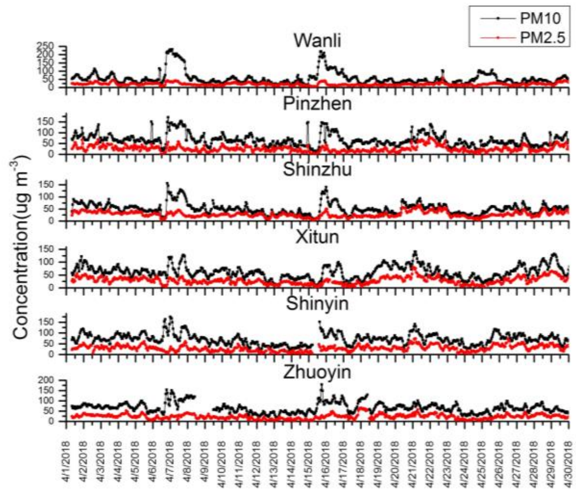


Fig. 2. Time series of the observed PM_{10} and $PM_{2.5}$ in Wanli, Pinzhen, Shinzhu, Xitun Sinyin and Zhuoyin stations during April 2018.

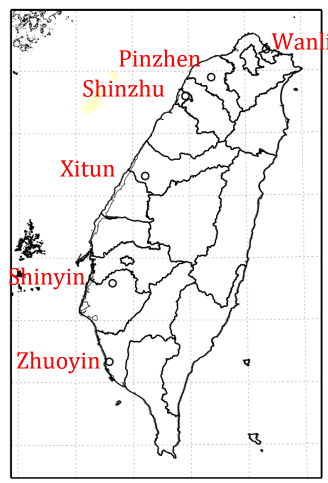


Fig. 3. The six ground observation sites.

Table 2 showed the evaluation performance for PM_{10} between the model and measurement. The statistical evaluation showed that the implementation of the latest physic-based dust scheme has significantly improved the performance of the model in projecting the particulate matter. For instant, the NMB for CMAQ_Nodust was -34.79%, and it further improved for CMAQ_Default and CMAQ_Revised with -27.99% and -23.15% respectively. Meanwhile, the new windblown dust module had also improved the ability of CMAQ in predicting PM_{25} as shown in Table 3. NMB for CMAQ_Default and CMAQ_Revised were recorded as -20.03% and -15.43% respectively which is lower than CMAQ_Nodust (-20.43%). Generally, the bias has been reduced by 11.6%

and 5% for PM_{10} and $PM_{2.5}$ respectively after the revised version of CMAQ model. Moreover, the time series of PM_{10} and $PM_{2.5}$ concentrations for CMAQ_Revised was observed to be closer than the measured dataset as compared to CMAQ_Nodust and CMAQ_Default.

The present result was consistent with the evaluation result showed by Dong at al. (2016) and Foroutan et al. (2017), where both studies suggested that the simulation has been improved after the implementation of the dust scheme. However, the performance of the model in particulate matter projection can be improved further by applying a better meteorological input data such as NCEP FNL Reanalysis data.

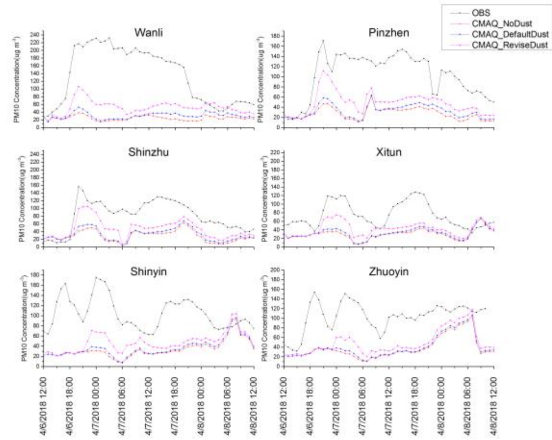
Table. 2. Evaluation of CMAQ PM_{10} in April 2018.

Variables	Simulation Scenarios		
	Nodust	Default	Revised
MeanObs	61.25	61.25	61.25
MeanMod	40.01	43.79	46.76
MB	-21.24	-17.45	-14.48
FB	-0.455	-0.348	-0.281
NMB	-34.79	-27.99	-23.15
NME	55.09	54.79	52.55
FAC2	0.761	0.863	0.918
NMSE	0.604	0.501	0.418
RMSE	43.05	42.69	40.74
MNB	-23.88	-13.64	-8.159

Table. 3. Evaluation of CMAQ PM_{25} in April 2018.

Variables	Simulation Scenarios		
	Nodust	Default	Revised
MeanObs	25.48	25.48	25.48
MeanMod	20.45	20.55	21.70
MB	-5.03	-4.93	-3.78
FB	-0.233	-0.228	-0.172
NMB	-20.43	-20.03	-15.43
NME	49.56	49.17	48.75
FAC2	0.932	0.936	1.00
NMSE	0.330	0.322	0.294
RMSE	16.42	16.31	16.65
MNB	-6.77	-6.31	0.643

(a)



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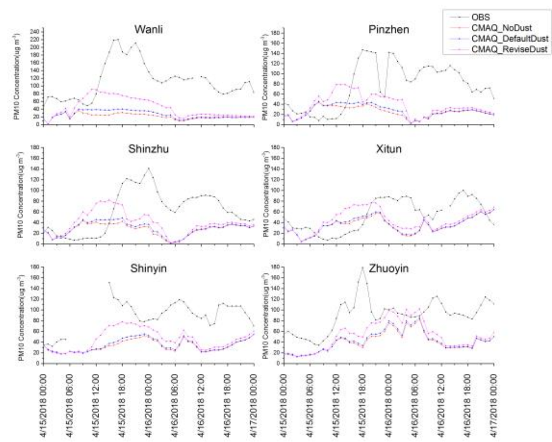
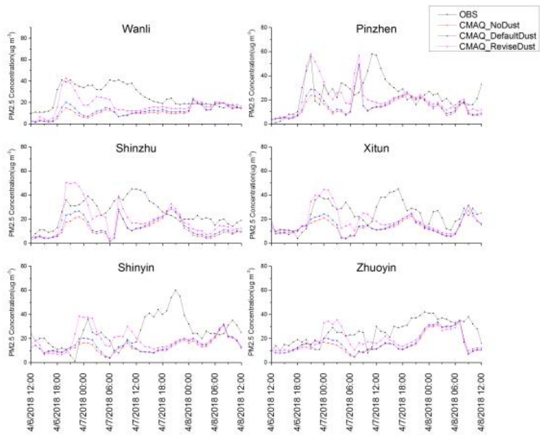


Fig. 4. Time series of the observed, CMAQ_Nodust, CMAQ_Default and CMAQ_Revised for PM_{10} in Wanli, Pinzhen, Shinzhu, Xitun Sinyin and Zhuoyin stations during (a) 7th April 2018 and (b) 16th April 2018.

(a)



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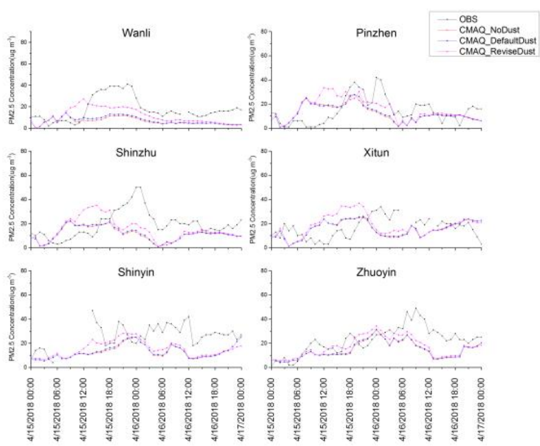

Fig. 5. Time series of the observed, CMAQ_Nodust, CMAQ_Default and CMAQ_Revised for PM_{25} in Wanli, Pinzhen, Shinzhu, Xitun Sinyin and Zhuoyin stations during (a) 7th April 2018 and (b) 16th April 2018.

4. CONCLUSION

East Asian Dust (EAD) is responsible in deteriorated air quality and poor visibility over East Asia (EA) over the past decade. The sources of the mineral dust particle, which originates from the deserts in China and Mongolia, bring adverse impact towards the downwind areas including China, Japan, Korea and Southeast Asia region. The present study analyzes the long range transport of EAD over EA during April 2018. The CMAQ (v5.2) model is applied with the implementation of the new windblown dust emission scheme modulated by Foroutan et al. (2017). Overall, the simulation underestimated the particulate matter (PM), probably due to the underestimation of modeled wind speed and overestimation of dry deposition. With the new dust module, the CMAQ simulation shows better performance than without the module incorporation in simulating both PM_{10} and $PM_{2.5}$, with normalized mean bias (NMB) of -23.15% and -15.43% improved from -34.79% and -20.43% respectively. The analysis of a dust storm episode during 7th and 16th April 2018 suggested that the CMAQ model is capable of capturing the dust aerosol concentration. The occurrence of the dust storm can be due to the Mongolian cyclonic which initiated the strong northwesterly wind over deserts regions. As for implication, the accuracy of CMAQ simulation can be enhanced by incorporating the new dust module in projecting the long-range transport of dust particle. However, the application of meteorological reanalysis input data into CMAQ model might be necessary for a better model performance.

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