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IMPACT OF FIELD BIOMASS BURNING ON LOCAL POLLUTION AND LONG-RANGE TRANSPORT OF $PM_{2.5}$ IN NORTHEAST ASIA IN AUTUMN 2014

Katsushige Uranishi[1], Fumikazu Ikemori[2], Hikari Shimadera[1], Akira Kondo[1] and Seiji Sugata[3]

[1]Graduate School of Engineering, Osaka University, Suita, Japan
[2]Nagoya City Institute for Environmental Sciences, Nagoya, Japan
[3]National Institute for Environmental Studies, Tsukuba, Japan

Abstract: This study focused on the impact of field biomass burning (BB) on local pollution and long-range transport of $PM_{2.5}$ in Northeast Asia in autumn 2014 with a huge field burning event. Air quality simulations by using WRF-CMAQ model were conducted in the year 2014 over the horizontal domains covering Northeast Asia including the mainland of Japan. In the baseline simulation (Base) case, emissions from field BB were derived from FINN v1.5 in the year 2014. The model approximately captured the daily mean $PM_{2.5}$ mass concentrations except for underestimates in autumn around Northeast China where the irregular field BB following the harvest in autumn could frequently occur. In order to clarify the underestimation of the emission from BB sources in China, the other simulation with five times boosted BB sources (FINN05) was conducted in addition to Base case. The model performance was significantly improved in FINN05 with smaller biases and higher indices of agreement between simulated and observed values, compared to those of Base.

In order to evaluate long-range transport of $PM_{2.5}$ from BB sources in China towards Japan, we compared CMAQ/BFM-estimated BB contributions both in Base and FINN05 cases with PMF-estimated BB contributions at Noto peninsula in Japan (Ikemori *et al.*, 2017). The CMAQ/BFM-estimated contributions of FINN05 better harmonized with the PMF-estimated contributions. The comparison of BB contributions estimated by the two antithetical models also indicated large underestimations in the current BB emission. .

Key words: $PM_{2.5}$, Long-range transport, Biomass burning, CMAQ, PMF, Emission uncertainty

INTRODUCTION

The specification of $PM_{2.5}$ sources is significant when planning strategies to reduce the $PM_{2.5}$ pollution level. Although air quality models (AQMs) are widely used to quantify the impacts of $PM_{2.5}$ sources, the performance of current AQMs for $PM_{2.5}$ simulation is not adequate for this purpose because of uncertainties associated with both AQMs themselves and their input data, such as meteorological fields and emissions. In particular, emission from biomass burning (BB) sources, such as crop field burning during the post-harvest seasons, is highly uncertain and may deeply affect the performance of AQMs because the emission has several uncertainties in the size and location of sources and in their temporal and spatial variability.

In recent years, several studies utilized AQMs to investigate the local pollution from BB in China, as reviewed by Chen *et al.* (2016). The previous studies mainly focused on localand domestic transport. The long-range transport of BB pollutants transported to Japan remains partially understood because there is no way to measure the source impact directly at the receptor sites in order to estimate the accurate contribution from BB sources. Meanwhile, we have reported recently that a comparison approach using the two antithetical models (PMF and CMAQ/BFM) enables us to identify which sectors of emission data have large biases (Uranishi *et al.*, 2017). The comparison approach is applicable to evaluation of the BB impact at the receptor sites on long-range transport of $PM_{2.5}$.

This study focuses on the impact of BB on local pollution and long-range transport of $PM_{2.5}$ in Northeast Asia in autumn 2014 with a huge field burning event. First, we evaluated the WRF/CMAQ performance for a local pollution in China with ground-level concentration data provided by Air quality data of China and also surveyed the impact of BB in China by conducting one-year simulations. Second, we utilized the analysis result of PMF-estimated contributions from BB at Noto peninsula in Japan (Ikemori *et al.*, 2017) to estimate the impact of BB on $PM_{2.5}$ in the pollution episode in Japan in October 2014, which could be affected by the long-range transport from BB sources in Northeast China. Finally, we integrated both results to estimate the impact of field BB on local pollution and long-range transport of $PM_{2.5}$ in Northeast Asia in autumn 2014 with a huge field burning event.

METHODOLOGY

Fig. 1 shows the modeling domains from East Asia domain (D1) to Japan domain (D2) and spatial distributions of fire spots (MCD14DL) during the target period (October 20 – November 9 in 2014) via Fire Information for Resource Management System (FIRMS, https://earthdata.nasa.gov/firms). Numerous fire spots derived from BB stud around Northeast China during the target period. Table 1 summarises WRF and CMAQ configurations. The details of chemistry and physics options are available in the documentation for the models.

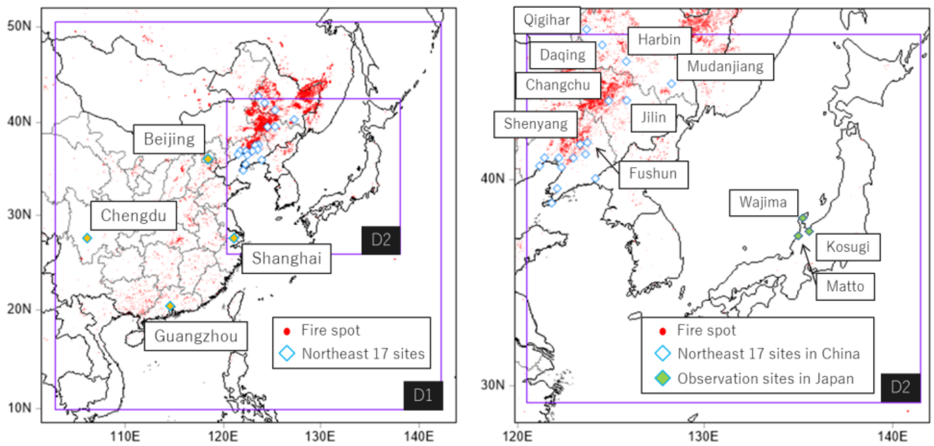

Figure 1. Modeling domains with locations of observation sites for $PM_{2.5}$ and fire spots during the target period (October 20 – November 9 in 2014)

Table 1. Configurations of AQMs

	Configurations
Model	Offline WRF v3.8.1 – CMAQ v5.0.2
Total duration for simulation	From January to December in 2014 with spin-up in December 2013
(The target period for analysis)	(October 20 – November 9 in 2014)
Domain	D1: East Asia 45km grid 107x107 (CMAQ)
	D2: Japan 15km grid 132x126 (CMAQ)
	34 layers (up to 100 hPa, 1st layer height ≈ 50m)
Meteorology	Geography data: USGS 30-sec topography and land-use
(WRF)	Analysis data: NCEP FNL, RTG_SST_HR, JMA MSM GPV
	Physics option: Kain-Fritsch, YSU(PBL), WSM6, Noah LSM and RRTM/Dudhia
	FDDA: $G_{t,\,q,\,uv} = 3.0\times10^{-4}\ s^{-1}$(D1, D2)
Emission	Asia: HTAPv2 (2010), Japan: EAGrid2010, JEI-DB (Vehicle), OPRF2010 (Ship)
	Biogenic: MEGANv2.04, Biomass burning: FINN v1.5
	Volcano: JMA & Aerocom
Boundary concentrations	MOZART-4/GEOS5 (D1)
Advection, Diffusion (CMAQ)	Yamartino/WRF-based scheme, Multiscale/ACM2
CMAQ chemistry	SAPRC07 & AERO6 with Aqueous chemistry

In the baseline simulation (Base) case, the emission from field BB was derived from FINN v1.5 in the year 2014. The other simulation with five times boosted BB sources (FINN05) was conducted in addition to Base case for comparison of the effect of the emission from BB sources in Northeast China. In order to evaluate the impact of field BB in Northeast China to $PM_{2.5}$ concetrations in Japan, an additional simulation without BB sources (noBB) was conducted to estimate the contribution from BB in Northeast

China by taking a difference between a target case (Base or FINN05) and noBB case (hereinafter called "CMAQ/BFM-estimated contribution"). Note that the CMAQ/BFM-estimated contributions from BB could be regarded as the contributions from BB except Japanese domestic BB because there are few domestic BB emission in Japan in FINN v1.5 of which emission is estimated by using satellite observations of active fires, such as fire spots by FIRMS as shown in Fig. 1.

The CMAQ performance for the local pollution in China was evaluated with ground-level concentration data provided by Air quality data of China (https://www.aqistudy.cn/historydata/index.php) which provides the data for 118 sites in D1 including 17 sites in Northeast China. In order to evaluate long-range transport of $PM_{2.5}$ from BB in Northeast China towards Japan, we utilized PMF-estimated BB contributions on the three sites (Wajima, Matto, and Kosugi in Fig. 1) in Noto peninsula in Japan (Ikemori *et al.*, 2017) as well as the CMAQ/BFM-estimated BB contributions. Ikemori *et al.* (2017) determined the BB contributions on $PM_{2.5}$ on the sites in Japan during autumn (October 22 - November 9) in 2014, using multiple-sites data including levoglucosan which is available for accurate identification of BB sources as the tracer species. In the next section, we focus on the comparison of PMF-estimated and CMAQ/BFM-estimated contributions from BB during the target period (October 20 – November 9) when a huge field burning event occured in Northeast China (Fig. 1) in order to evaluate the long-range transport of $PM_{2.5}$ towards Japan.

RESULTS AND DISCUSSION

The local pollution from BB in China

The CMAQ performance for $PM_{2.5}$ concentrations was evaluated with ground-level observation data in China by means of time series comparison and statistical index of model performance, namely, the index of agreement (IA). Fig. 2 shows the comparison of the observed and simulated daily mean concentrations of $PM_{2.5}$ for the site-averaged products for the entire China and Northeast China. The model simulated the day-to-day variation patterns for the site-averaged products in the entire China well, including the occurrence of several high concentration peaks (Fig. 2(a)). However, the model failed to reproduce the $PM_{2.5}$ concentration in October in Northeast China with large underestimation of simulated values in Base case (Fig. 2(b)).

Fig. 3 shows the comparison of the results of Base and FINN05 cases versus the observed values in terms of the mean concentrations and the standard deviations of $PM_{2.5}$ on the observation sites in China during the target period. Base case shows relatively large differences in Northeast China versus the observed data compared to FINN05 case. The favorable performance in FINN05 case was also supported by the higher IA values for 17 sites in Northeast China (0.73 in FINN05 case versus 0.53 in Base case) as well as those for each monitoring sites as shown in Fig. 3. According to Zhou *et al.* (2017), burning activity mainly occurs in the harvest season. Particularly in Northeast China, the study shows high values of BB emission rate primarily due to corn harvesting in October. Thus, the underestimation of $PM_{2.5}$ concentrations in Base case is assumed to be attributed to the underestimation of emission from BB during the target period. These results also reveal the limitation of the estimation method by using satellite observations of active fires in FINN. Note that BB emission still has several uncertainties in the size and location of sources as well as in their temporal and spatial variability despite the underestimation of BB emission which was illustrated by these results to some extent.

The long-range transport from BB occured in China towards Japan

Fig. 4 shows the comparison between PMF-estimated and CMAQ/BFM-estimated daily mean contributions from BB on $PM_{2.5}$ mass on the three sites in Noto peninsula in Japan during the target period. The PMF-estimated BB contributions on the three sites were in common and showed relatively high in the three days (October 27 – 29), compared to other days in the target period. On the other hand, for the CMAQ/BFM-estimated BB contributions in Base case, large underestimations consistently occured specifically in the three days, compared to FINN05 case which showed the reasonable agreement between PMF-estimated and CMAQ/BFM-estimated contributions.

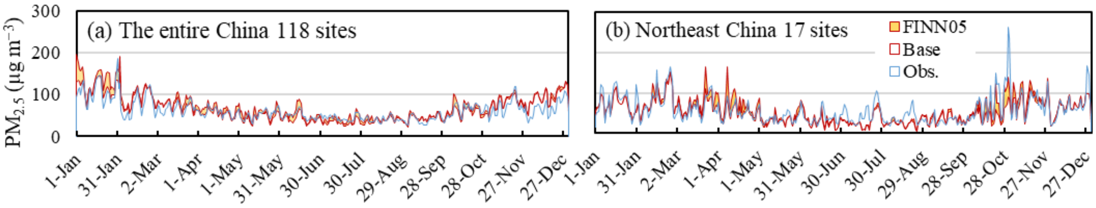

Figure 2. Time series of the observed and simulated daily mean concentrations of (a) $PM_{2.5}$ in the entire China and (b) $PM_{2.5}$ in Northeast China in the year 2014. The red lines show the simulated values in Base and FINN05 cases at the grid cell corresponding to each observation site, whereas the blue lines show the observed values.

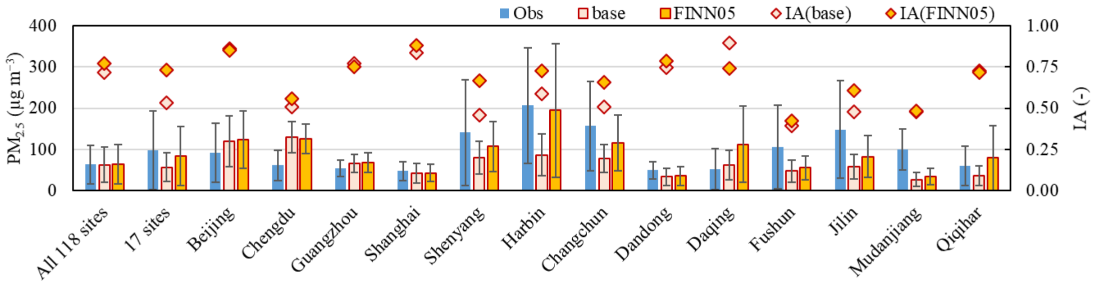

Figure 3. Comparison of the results of Base and FINN05 versus the observed values in terms of the mean concentrations, the standard deviations, and IA of $PM_{2.5}$ on the observation sites in China during the target period. The blue bars show the observed values, whereas the the red and orange bars show Base and FINN05 cases, respectively.

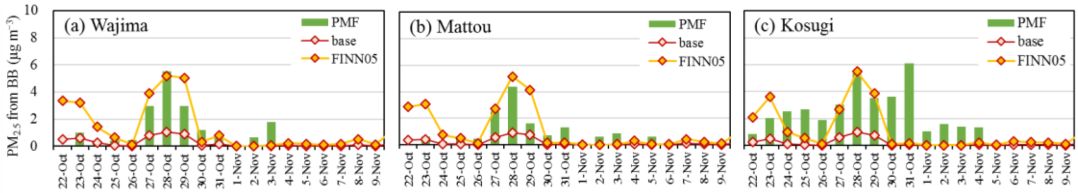

Figure 4. Comparison of the daily mean contributions from BB on $PM_{2.5}$ concentrations at 3 sites in Noto peninsula in Japan in 2014. The green bars show PMF-estimated daily mean contributions from BB, whereas the the red and orange diamonds show CMAQ/BFM-estimated daily mean contributions in Base and FINN05 case, respectively.

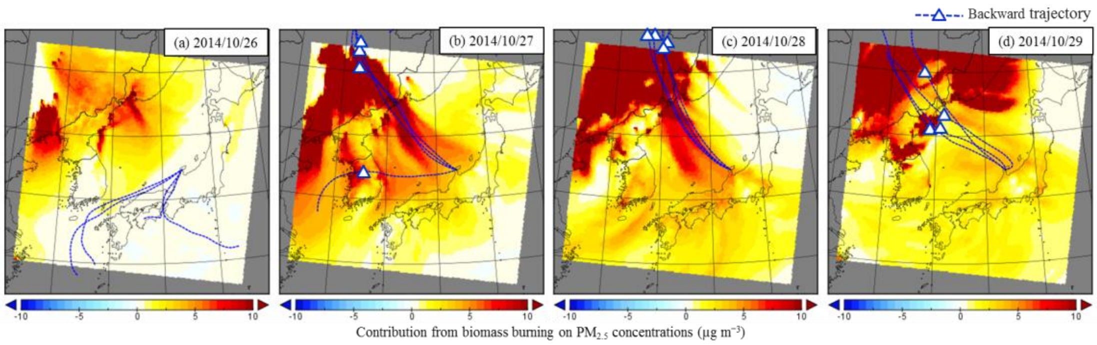

Figure 5. Spatial distributions of CMAQ/BFM-estimated daily mean contributions from BB on $PM_{2.5}$ concentrations in FINN05 case and 2-day backward trajctories started at an altitude of 1,500 m at Wajima in Noto peninsula in Japan. The blue lines show the backward trajectories run four times a day (0, 6, 12, and 18 UTC) for each day (October 26 – October 29), whereas the triangles show the air parcels position back in 24 hours ago for each backward trajectories.

Fig. 5 shows spatial distributions of CMAQ/BFM-estimated daily mean contributions from BB on $PM_{2.5}$ concentrations in FINN05 case and 2-day backward trajectories started at an altitude of 1,500 m at Wajima in Noto peninsula in Japan during October 26 – 29. Backward trajectories were computed with the HYSPLIT model operated by Trajstat v1.2.2.6. The trajectory analysis revealed that BB pollutants in Northeast China were directly transported to Wajima site in Noto peninsula in Japan during October 27 – 29 when relatively high contributions from BB was identified by PMF analysis (Fig. 5(b), (c), and (d)). Moreover the spatial distributions of the daily mean contributions from BB described that the air parcels with pollutant derived from BB were transported to Noto peninsula from Northeast China during October 27 – 29 (Fig. 5(b), (c), and (d)). Consequently, FINN05 case presented the favorable results consistently on local pollution and long-range transport of $PM_{2.5}$. We concluded that boosted BB sources is preferable in conducting a simulation of air quality in Northeast Asia which could be deeply affected by BB emission, such as the crop field burning.

CONCLUSION

This paper described the impact of BB on local pollution and long-range transport of $PM_{2.5}$ in Northeast Asia in autumn 2014 with a huge field burning event. The CMAQ performance for $PM_{2.5}$ concentrations was evaluated to estimate the local pollution of $PM_{2.5}$ in China. The model in Base case captured the temporal and spatial variation patterns of $PM_{2.5}$ mass for the most part, including the occurrence of several high concentration peaks. However, the model in Base case failed to reproduce the $PM_{2.5}$ concentration in October, particularly in Northeast China where the irregular open field burning following the harvest could frequently occur. Meanwhile, FINN05 case presented the favorable performance supported by the higher IA values for 17 sites in Northeast China as well as those for each monitoring sites, as shown in Fig. 3. These results imply that BB emission has a large uncertainty in Northeast China. In addition, we compared both PMF-estimated and CMAQ/BFM-estimated contributions from BB during the target period when a huge field burning event occured in Northeast China (Fig. 1) in order to evaluate the long-range transport of $PM_{2.5}$ towards Japan. In contrast to Base case, FINN05 case showed the reasonable agreement between PMF-estimated and CMAQ/BFM-estimated contributions with the similar level and day-to-day variation patterns for BB contributions during the target period. As a consequence, this comparison approach by using PMF and CMAQ/BFM allows us to illustrate that a boosted BB emission is preferable in conducting a simulation affected by BB emission.

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