Influence of the emission sources on O_3 and $PM_{2.5}$ concentration in Taiwan using CMAQ-HDDM

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Introduction

Taiwan is an island on the northwest side of the Pacific Ocean. According to Taiwan emission inventory, western Taiwan has larger emissions and major from metropolitan cities, coal-fired power plants, industrial parks, vehicle exhausts and burnings of agriculture wastes. Local emissions will result in severe pollution events, especially under the weak synoptic weather condition (Hsu and Cheng, 2019).

Sensitivity analysis methods, such as brute force method (BFM) and high-order decouple direct method (HDDM), provides the relationship between the emission sources and the ambient air pollutant concentrations. HDDM had been implemented within CMAQ and simultaneously calculated various experiments to reduce inquired time. Moreover, HDDM can accurately capture the nonlinear response of O_3 and $PM_{2.5}$ to their precursors.

The study episode (Nov. 6-8, 2018) was associated with a weak synoptic weather condition and the stagnant wind trapped the air pollutants near the emission source region. This study utilized CMAQ-HDDM to investigate the impact of different emission sources on O_3 and $PM_{2.5}$ concentrations on Nov. 8, 2018.

Methodology

High-order Decoupled Direct Method (HDDM) directly calculates semi-normalized first- and second-order sensitivity coefficients as eq.1 and eq.2. The changed concentration can be estimated by following eq.3 with a specific perturbation($\delta\varepsilon$) (Hakami et al.,2003; Hakami et al.,2004).

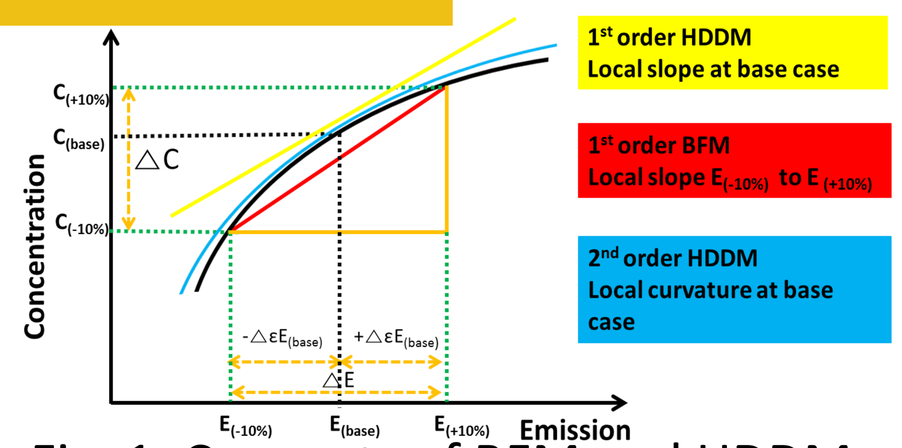

Fig. 1. Concepts of BFM and HDDM.

$$S_j^{(1)} = \frac{\partial C}{\partial \varepsilon_j} \text{ (eq.1) 、 } S_j^{(2)} = \frac{\partial^2 C}{\partial \varepsilon_j^2} \text{ (eq.2) 、 } \Delta C \approx \delta\varepsilon_j S_j^{(1)} + \frac{1}{2}\delta\varepsilon_j^2 S_j^{(2)} \text{ (eq.3)}$$

C denotes the ambient concentration and ε_j is relative perturbations ($\delta\varepsilon = \delta p/p$).

Model configurations and experiment design

The meteorological data for CMAQ was from WRF two-nested domain (Fig 2.) The detail setup of WRF and CMAQ models were illustrated in Table 1.

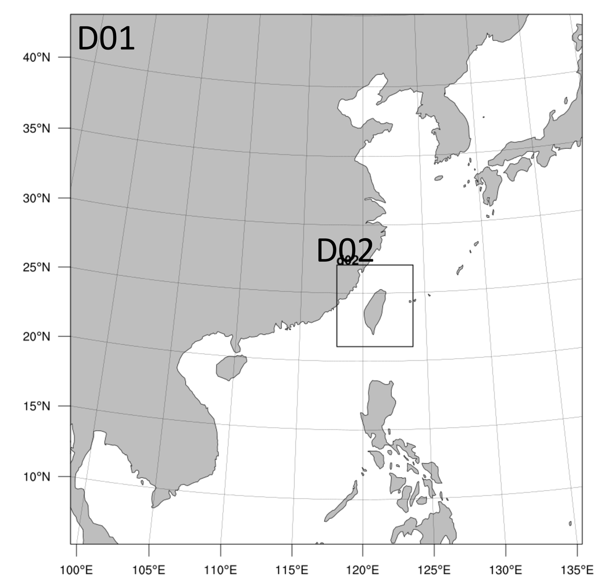

Fig. 2. Simulated domain.

HDDM calculated the sensitivities to NO_x and SO_2 from point sources, NO_x and VOC from line sources, and SO_2 and VOC from area sources in this study.

Table 1. WRF and CMAQ model configurations.

WRFv3.7.1	D01	D02
Simulated period	2018/11/03 – 2018/11/09	
Resolution	15 km	3km
Reanalysis data	NCEP FNL (0.25° x 0.25°, 6hr)	
Vertical layers	48 (top 5000pa)	
PBL scheme	YSU	
CMAQ5.0.2	**D02**	
Simulated period	2018/11/03 – 2018/11/10	
Resolution	3km	
Emissions	TEDS10 / MEGANv2.04	
Mechanism	CB05tucl – AE6	
ICON/BCON	Profile	

Results

Observation vs Simulation:

Model underestimated the $PM_{2.5}$ during daytime, especially in coastal area that can be due to higher wind speed in model. During nighttime, model underestimated O_3 due to the overestimation of NO_x.

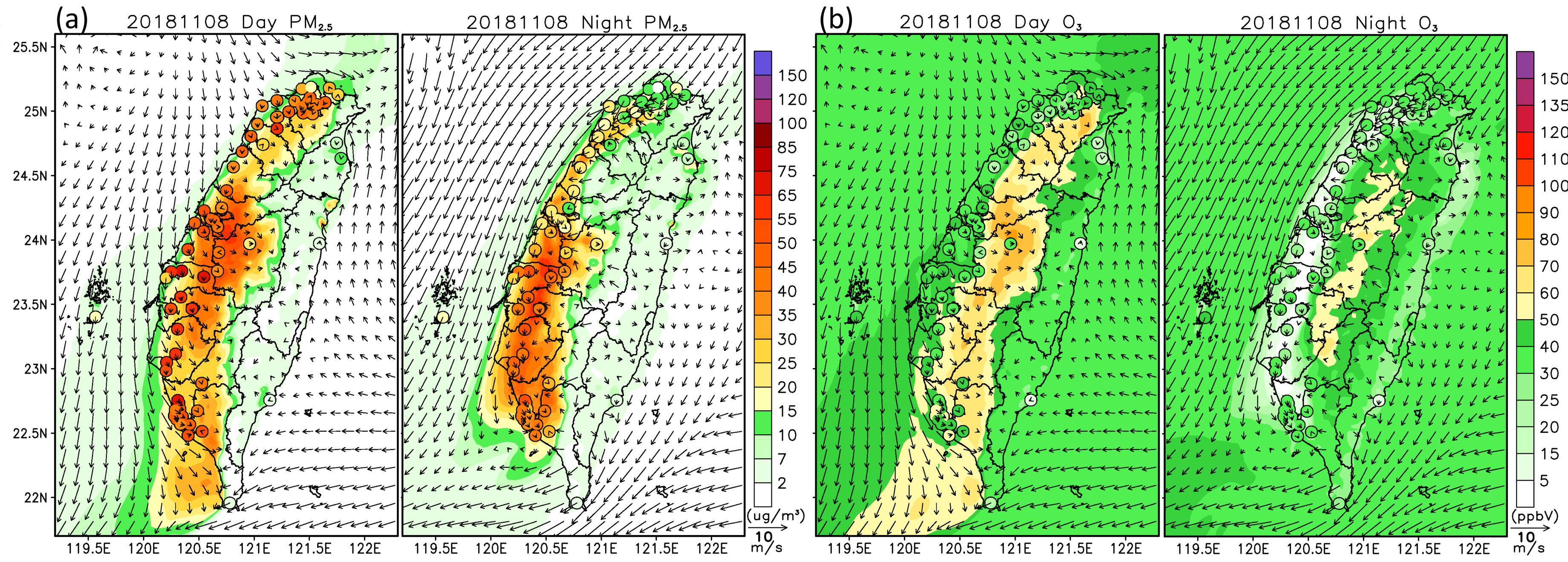

Fig. 3. Average spatial distribution of simulated (shaded) and observed (dots) (a)$PM_{2.5}$ and (b)O_3 with wind field during daytime (8-17LST) and nighttime.

HDDM results ($\delta\varepsilon$=-0.3):

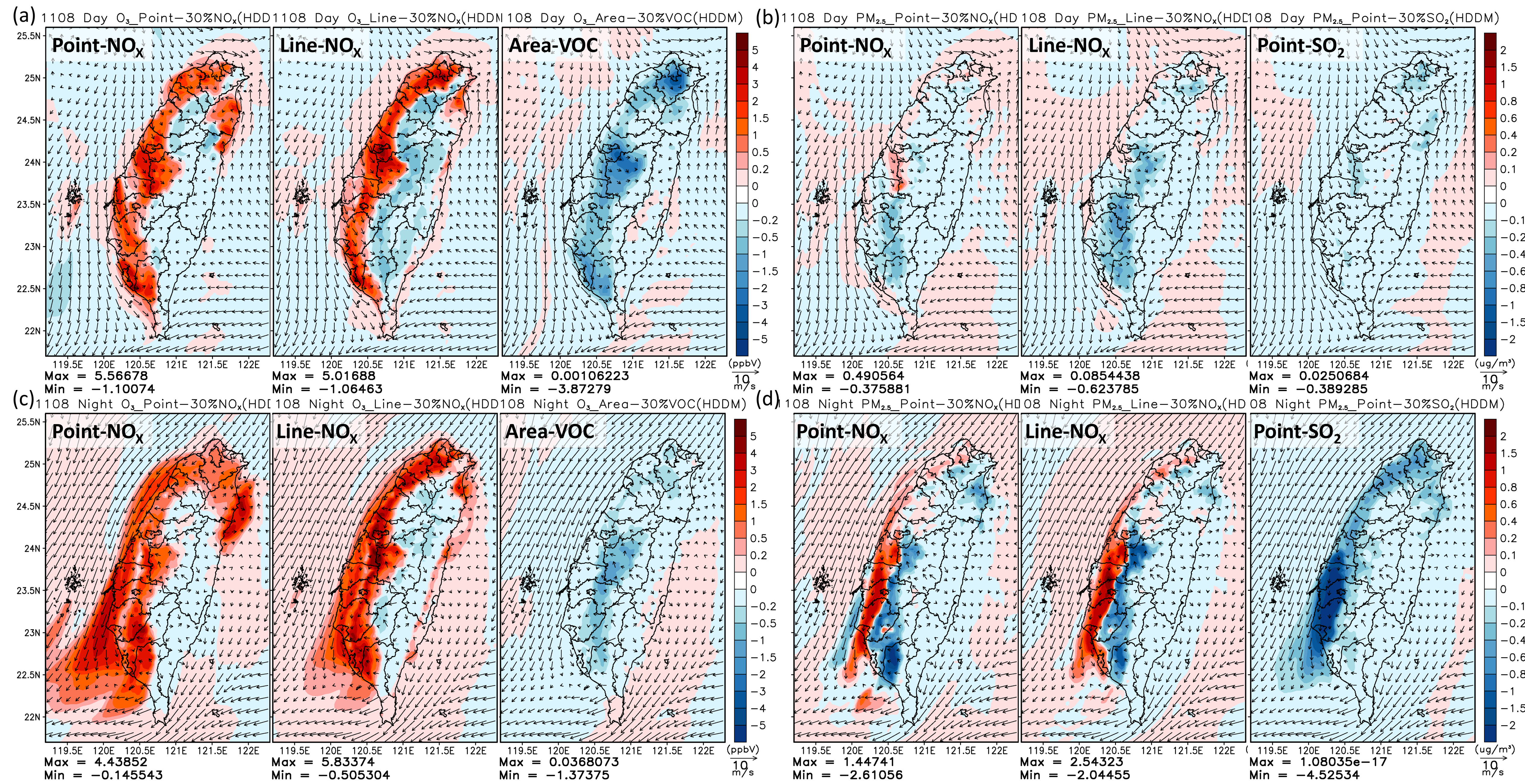

Fig. 4. Average spatial distribution of changed (a), (c) O_3 and (b), (d) $PM_{2.5}$ concentrations to reduce 30% of different species from emission sources during (a), (b) daytime (8-17LST) and (c), (d)nighttime.

Conclusions

1. During daytime, reducing NO_x emissions from both point and line sources can increase O_3 in downwind area and near sources regions due to decrease of titration effect, and slightly reduce $PM_{2.5}$ in the inland regions.
2. During nighttime, the $PM_{2.5}$ increase in coastal areas due to increase of O_3 concentration. Removing SO_2 emissions from point sources can effectively decrease $PM_{2.5}$ in central Taiwan.
3. Reducing the VOC emissions from both area and line sources can reduce O_3 concentration, especially in metropolitan cities, and area sources had larger impact. The influence on $PM_{2.5}$ is smaller than NO_x and SO_2 emissions.

References

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