The Role of Weather Conditions Conducive to Severe Haze and Regional Transport of Air Pollutants of Three Heavy-Polluted Episodes in Henan Province, China during 2015-2016

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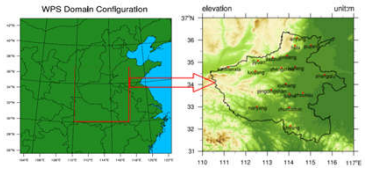
Introduction

The frequency of Henan winter severe haze episodes has increased substantially over the past decades, and it is commonly attributed to increased pollutant emissions resulted from China's rapid economic development. Henan Province is one of the most polluted areas in the Beijing-Tianjin-Hebei and its outskirts. Due to the prevailing surface wind and the Taihang Mountains terrain in the west part of Beijing-Tianjin-Hebei, a pollutant transport passage has been formed. The objective of this work is to quantitatively assess the impact of the pollutants transport from neighboring provinces.

Model Setup

Modeling Domain and Configuration



Model Attribute	Configuration Option
Model	WRF/Chem V3.4
Domain and Resolution	6km x 6km over Henan and neighboring provinces
Simulation Period	25 Nov. ~ 31 Dec., 2015
Meteorological ICs/BCs	NCEP-FNL reanalysis data
Anthropogenic Emissions	MEIC (revised 2012)
Radiation	Goddard shortwave Scheme and RRTM Scheme
PBL	YSU Scheme
Land-Surface	Noah surface land-surface model
Microphysics	WSM 6 Scheme
Cumulus Parameterization	Kain-Fritsch Cumulus Scheme
Gas-Phase Chemistry	RADM2
Aerosol Module	MADE/SORGA
Aerosol Feedback	Turn on
Cloud Feedback	Turn on

Simulation Design

Simulation set 1 (SS1): (1) base source emission (SS1-B1); (2) Zero out within Henan province (SS1-S1).
Simulation set 2 (SS2) focuses on Zhengzhou (ZZ): (1) base (SS2-B1); (2) zero out emission within Henan province (SS2-S1); and (3) zero out within ZZ (SS2-S2).
Simulation set 3 (SS3): (1) base (SS2-B1); zero out emission within (2) Henan province (SS3-S1); (3) Beijing-Tianjin-Hebei Province (SS2-S2); (4) Shandong Province (SS3-S3); (5) Jiangsu province and Anhui province (SS3-S4); (6) Hubei province (SS3-S5); and (7) Shanxi province (SS3-S6).

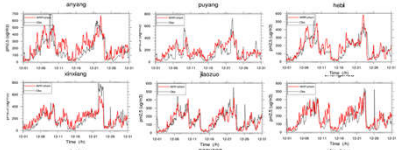
Model Evaluation Method and Dataset

- Observation are available in 18 cities in Henan province. They're Anyang (AY), Puyang (PY), Hebi (HB), Xinxiang (XX), Jiaozuo (JZ), Jiyuan (JY), Sanmenxia (SMX), Luoyang (LY), Zhengzhou (ZZ), Kaifeng (KF), Shangqiu (SQ), Xuchang (XC), Pingdingshan (PDS), Luohe (LH), Zhoukou (ZK), Nanyang (NY), Zhumadian (ZMD), and Xinyang (XY).
- Model evaluation includes time series plots and correlation analyses

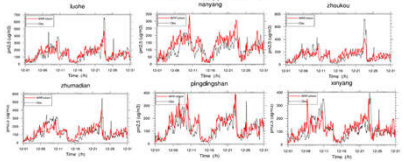
Model Evaluation

Temporal Variation

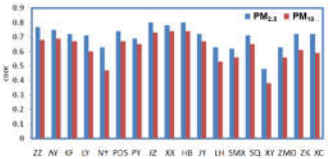
$PM_{2.5}$



PM_{10}

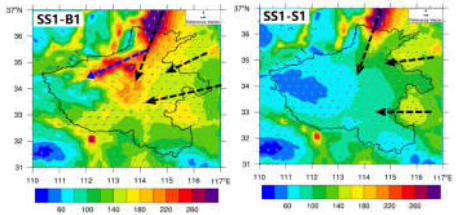


Correlation



Source Sensitivity

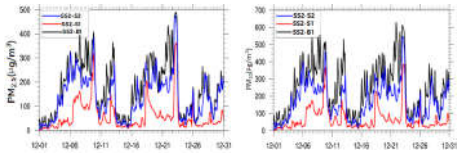
Simulation Set 1



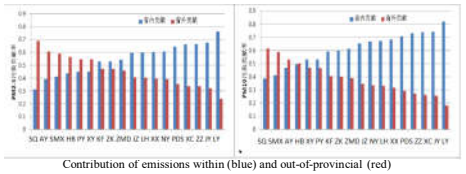
$PM_{2.5}$ concentration over Henan province (shaded: $PM_{2.5}$ concentration; vector, 10m wind

Three main transport channels to transport pollutants to Henan from (1) Hebei Province; (2) Shandong province; (3) Anhui and Jiangsu provinces.

Simulation Set 2



About 80% (70%) of $PM_{2.5}$ (PM_{10}) pollutants is from outside of ZZ, local contribution is ~ 20% (30%). Emission outside from Henan accounted for ~ 34% (27%), $PM_{2.5}$ is more easily transported over long distances than coarse.



Contribution of emissions within (blue) and out-of-provincial (red)

Transport from out-of-provincial is greater than that within SQ, AY, SMX, HB, PY, and XY for $PM_{2.5}$ and that within SQ, SMX, and AY for PM_{10}. $PM_{2.5}$ pollutants are more easily transported over long distances than coarse particles.

The contributions of local and neighboring provincial emissions ($PM_{2.5}$) during three episodes in 2015

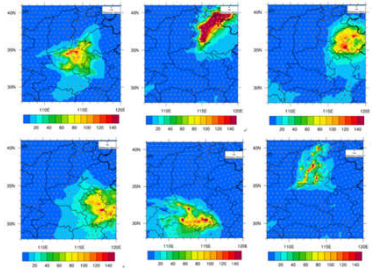
Time	Henan	Beijing-Tianjin-Hebei	Shandong	Anhui and Jiangsu	Hubei	Shanxi
1127-1201	52.9%	2.2%	2.4%	6.0%	20.7%	3.9%
1205-1214	44.2%	8.0%	9.8%	17.7%	8.8%	5.2%
1219-1225	44.1%	6.3%	9.8%	18.5%	9.1%	10%

The local emissions are top contributor to $PM_{2.5}$, the second largest contributor is the emissions in Hubei province for the first episode, and the emissions in Jiangsu and Anhui provinces during the second and the third episodes.

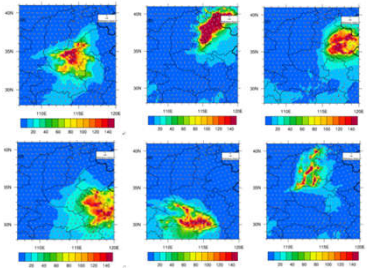
Simulation Set 3

Contributors of local and neighboring emissions (Henan, Beijing-Tianjin-Hebei, Shandong, Jiangsu and Anhui, Hubei, and Shanxi).

$PM_{2.5}$ ($\mu g/m^3$)



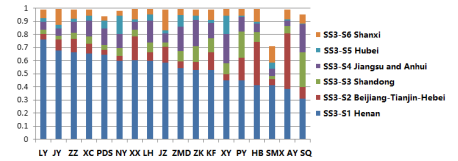
PM_{10} ($\mu g/m^3$)



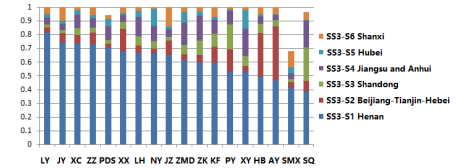
Their contributions varied mainly because of wind direction and speed. Emissions from each adjacent province affect $PM_{2.5}$ in Henan.

% Contribution of Emissions from Henan and Adjacent Provinces to $PM_{2.5}$/PM_{10} in Cities in Henan

$PM_{2.5}$



PM_{10}



Local and neighboring provincial emissions contribute differently O_3, $PM_{2.5}$ and PM_{10} in each city in Henan due in part to weather condition. Local emissions account for more than 40%, Beijing-Tianjin-Hebei (35%), Jiangsu and Anhui (21%), and Shandong (20%) are the main pollutant sources corresponding to the three pollution transport channels.

Summary

- The local emission is the top contributor to pollution. Emissions from neighboring provinces is the second largest contributor.
- The contributions from neighboring provinces varied because of different pre-existing pollution, wind direction, and pollution episodes.
- There are three main transport channels to transfer pollutants to Henan from neighboring provinces. Beijing-Tianjin-Hebei, Jiangsu and Anhui, and Shandong are the main pollutant sources corresponding to three channels.

Acknowledgements

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