

# Source attribution of PM<sub>2.5</sub> for Korea during the KORUS-AQ campaign

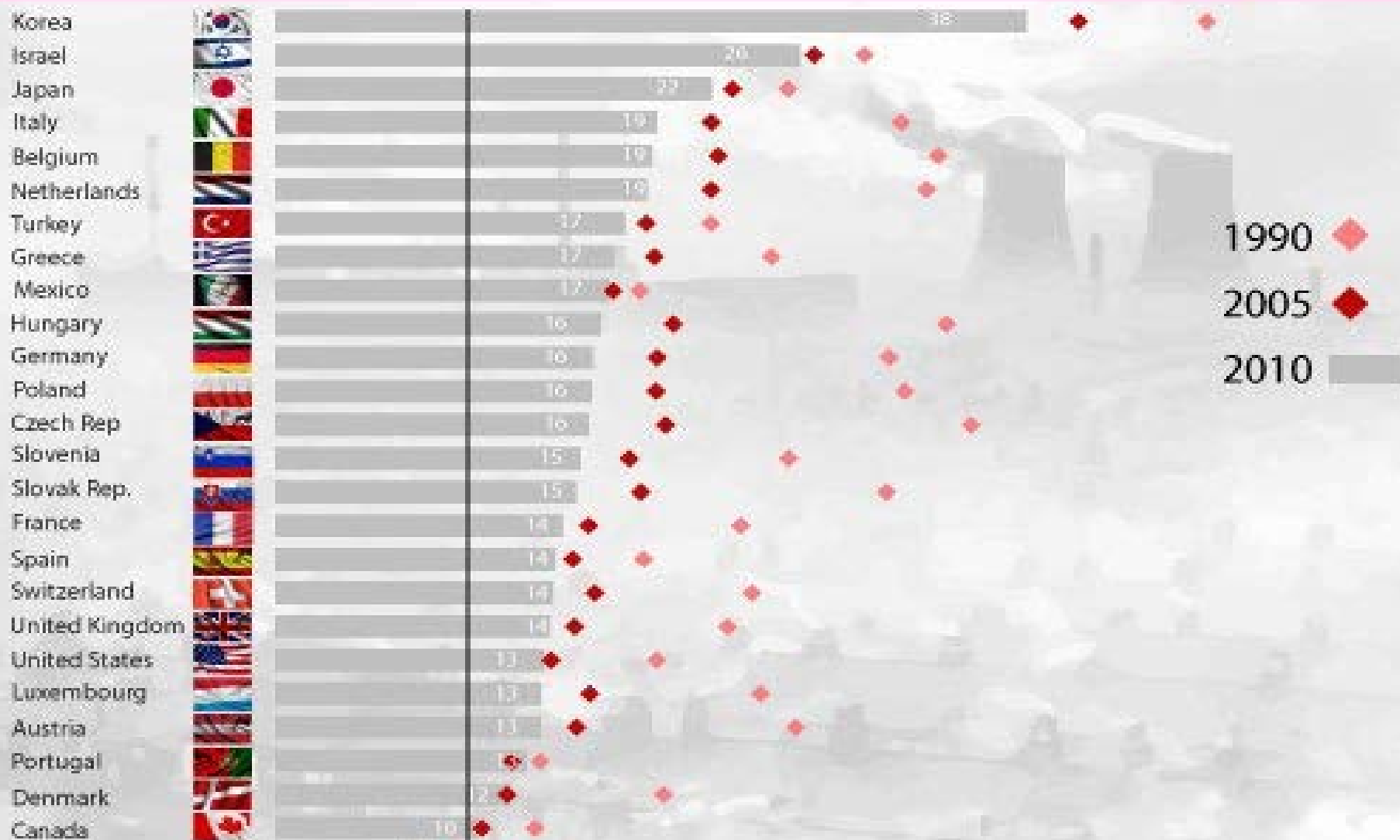
Jinkyul Choi<sup>1</sup>, Rokjin J. Park<sup>1</sup>, Hyung-Min Lee<sup>1</sup>, Seungun Lee<sup>1</sup>, Duseong S. Jo<sup>1</sup>, Jaemin I. Jeong<sup>1</sup>, Daven K. Henze<sup>2</sup>, Jung-Hun Woo<sup>3</sup>, Soo-Jin Ban<sup>4</sup>, Seogju Cho<sup>4</sup>, Min-Do Lee<sup>4</sup>, Cheol-Soo Lim<sup>4</sup>, Mi-Kyung Park<sup>4</sup>, Hye J. Shin<sup>4</sup>, David Peterson<sup>5</sup>, Chang-Keun Song<sup>6</sup>

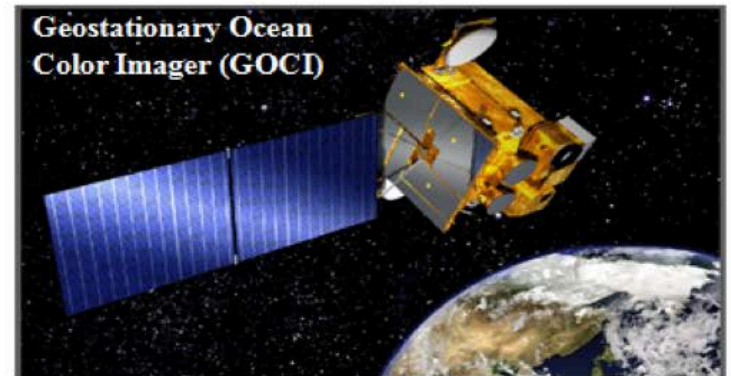
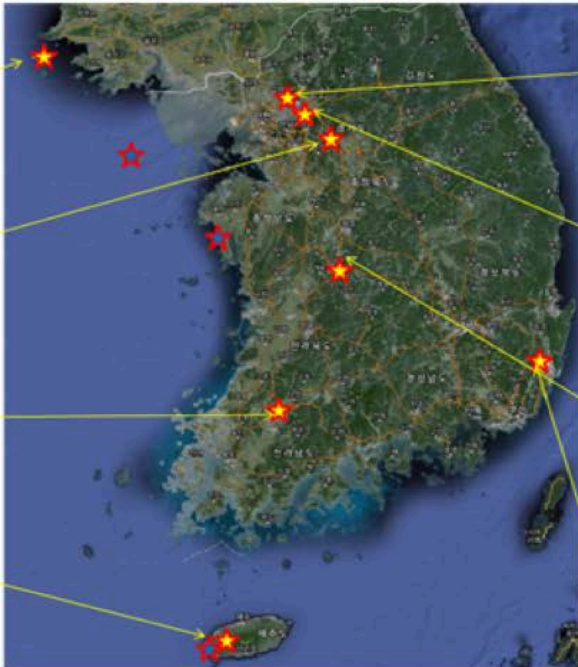
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2. Department of Mechanical Engineering, University of Colorado, Boulder, CO, USA
3. Department of New Technology and Fusion (DATF), Konkuk University, Seoul, Republic of Korea
4. National Institute of Environmental Research (NIER), Incheon, Republic of Korea
5. U.S. Naval Research Laboratory, Monterey, CA, USA
6. Ulsan National Institute of Science and Technology (UNIST), Ulsan, Republic of Korea



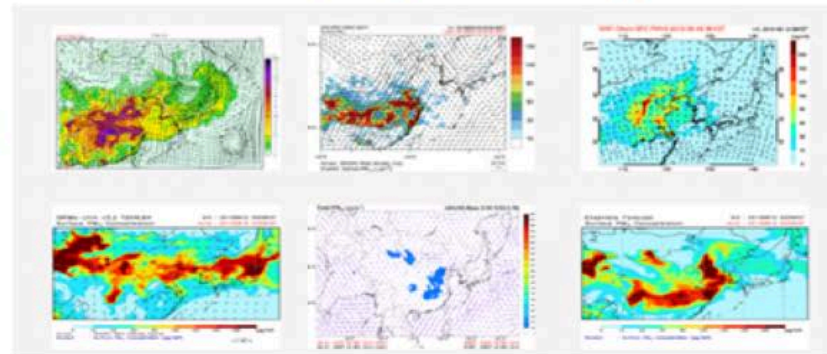
# Population exposure to fine particulates

(PM<sub>2.5</sub>) Average annual exposure levels of an average resident in microgram per m<sup>3</sup>



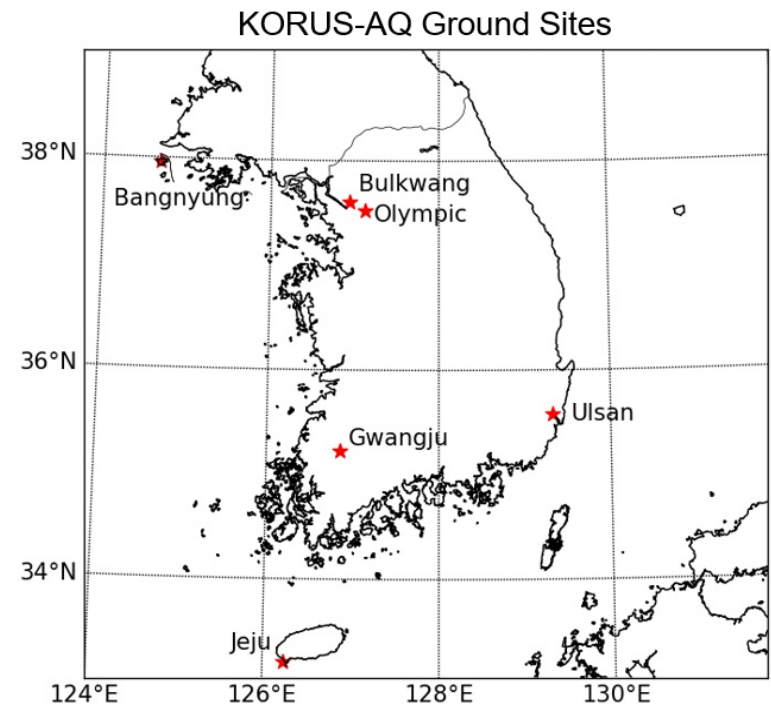


**Korean and US Air Quality Model Forecasts**

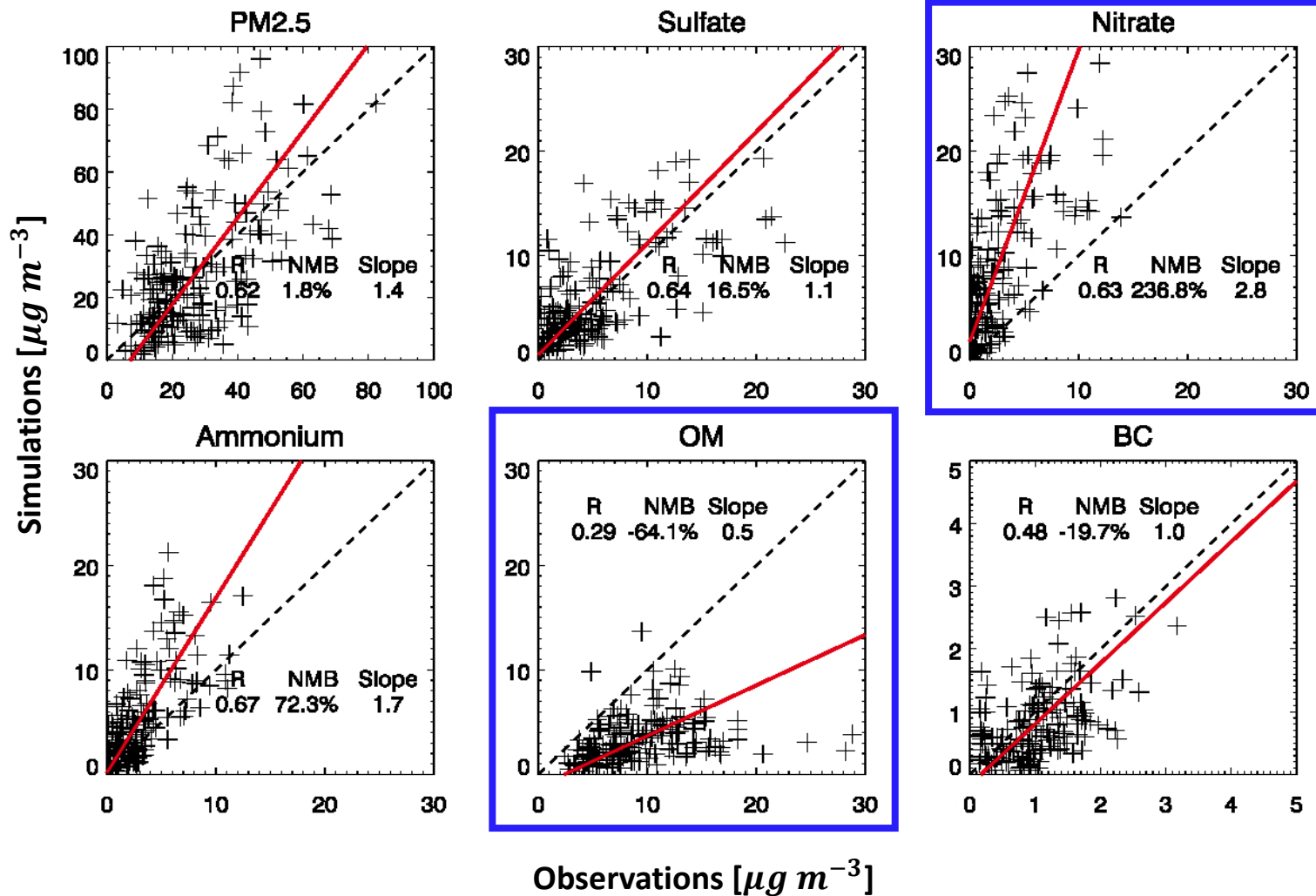


# Model Setup & Observation Sites

- GC-adj v35k
- Meteorology: GEOS-FP
- Resolution:  $0.25^\circ \times 0.3125^\circ$  with 47 levels
- Domain: Nested SD (100-140E, 20-50N)
- Period: 2016. 05. 01 – 06. 10
- Anthropogenic emissions: KU-CREATE Ver. 2.0
- $PM_{2.5} = SO_4^{2-} + NO_3^- + NH_4^+ + BC + 2.1 \times OC$

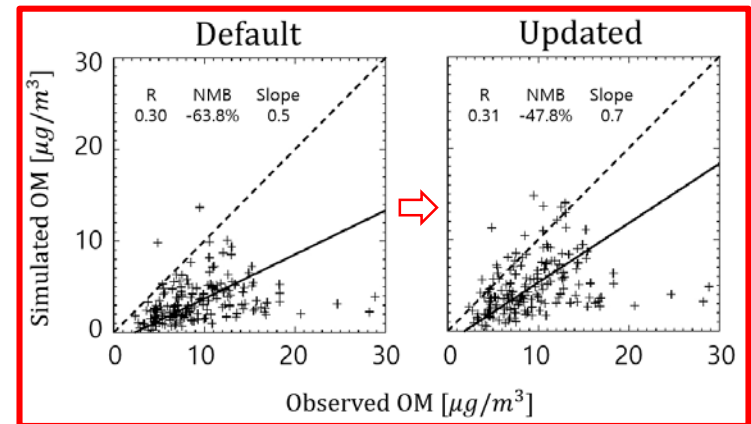
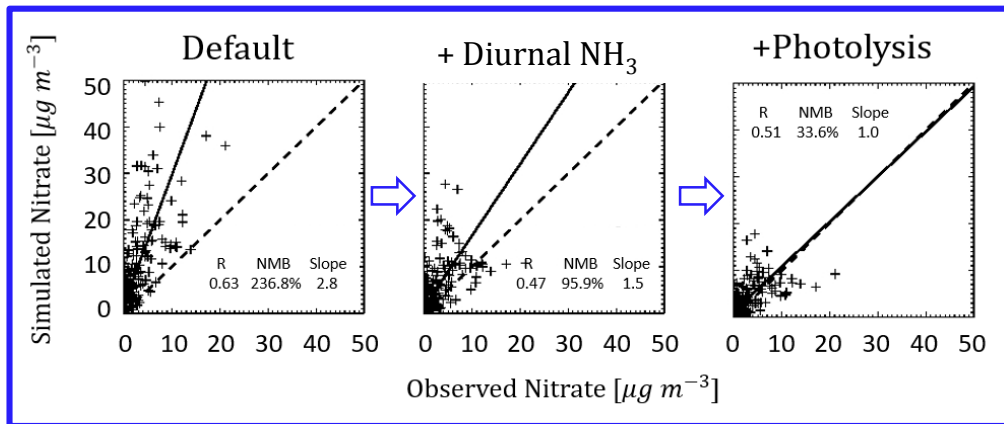


# Model Validation

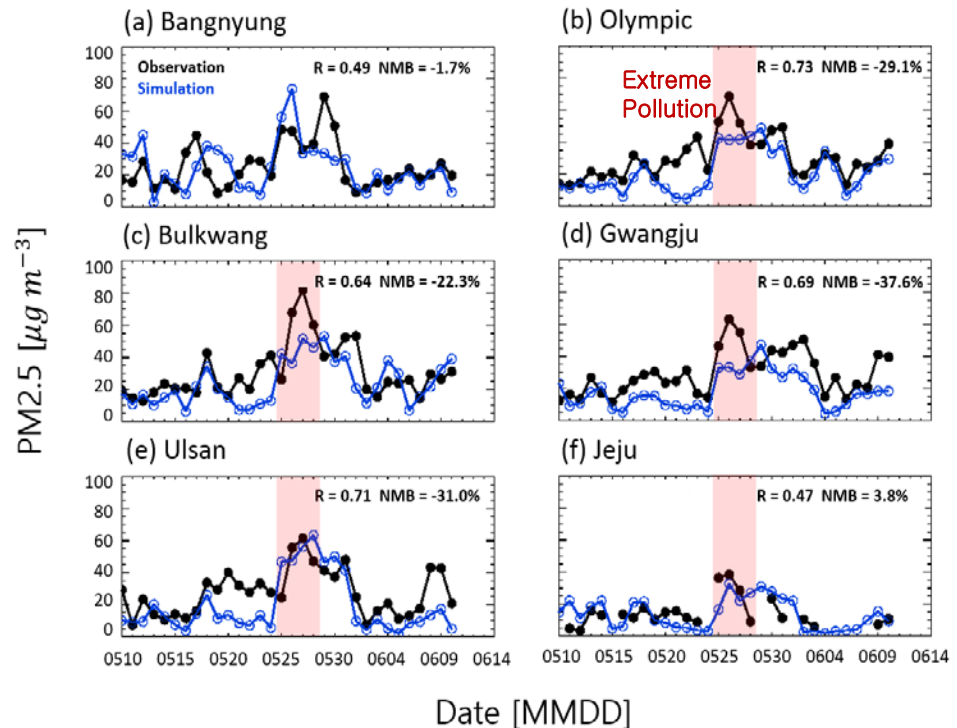
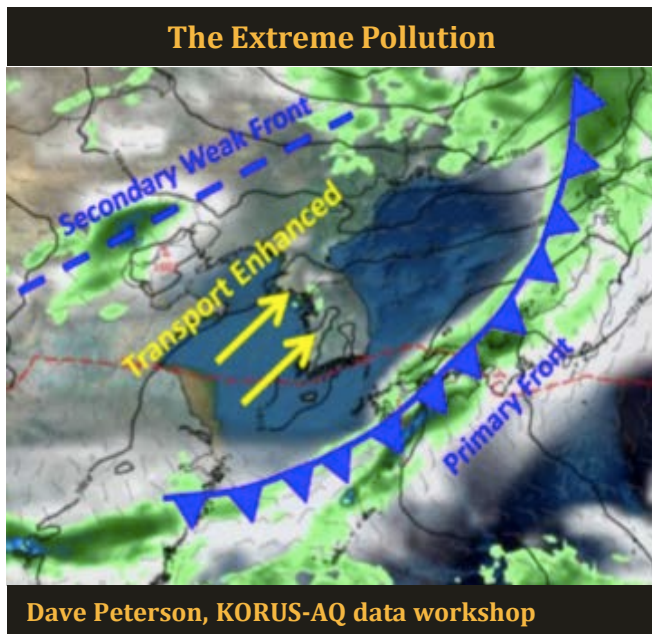


# Model Updates

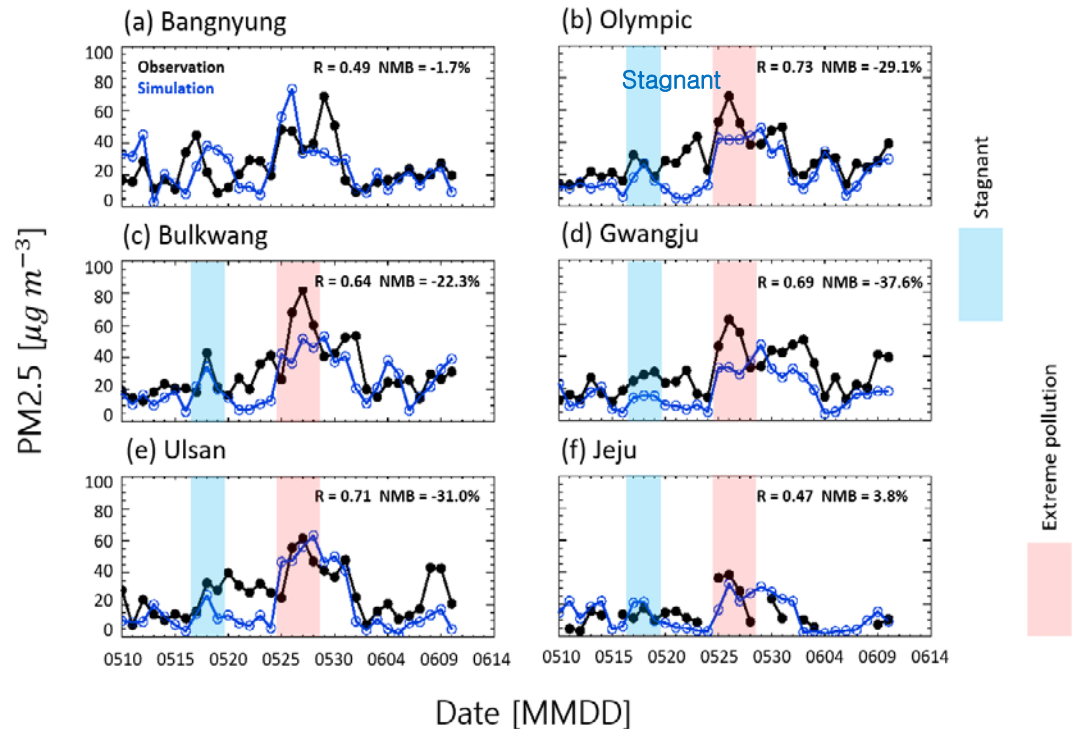
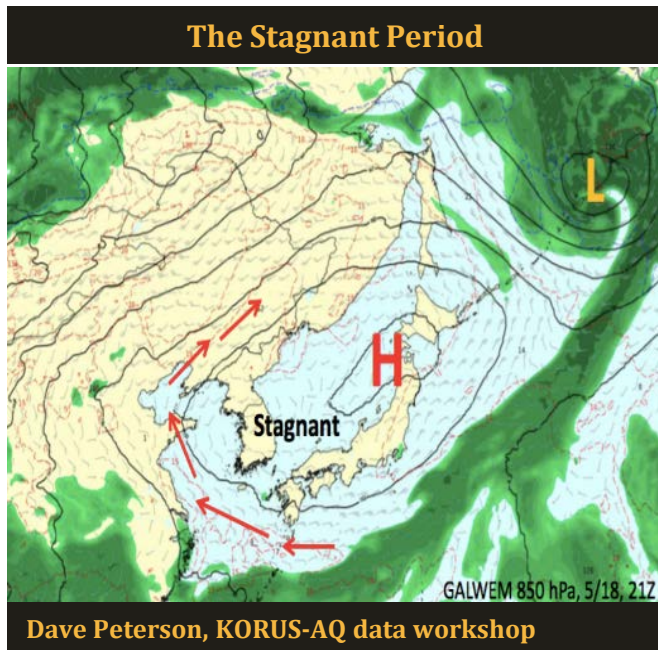
1. Diurnal variation in  $\text{NH}_3$  emission [Poulain et al., 2011; Zhu et al., 2015]
2. Additional loss of  $\text{NO}_3^-$  by photolysis [Ye et al., 2017; Lee et al., in prep.]
3. Benzene, toluene, xylene oxidation (benzene, toluene, xylene) and SOA yields from VBS approach [Henze et al., 2008; Jo et al., 2013]



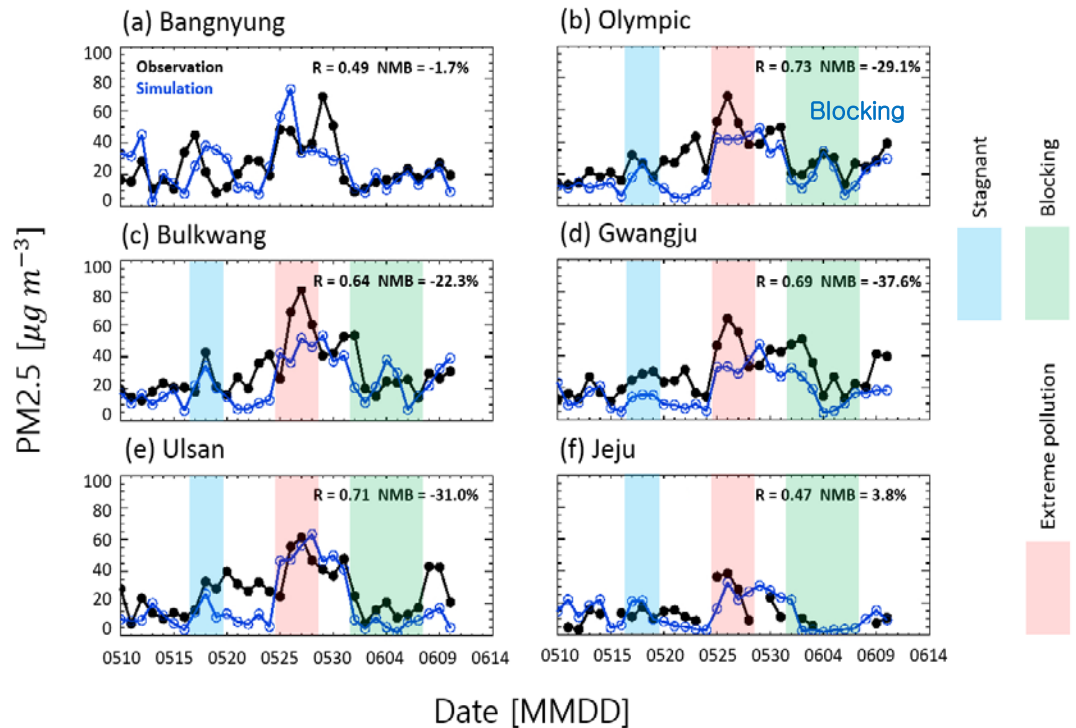
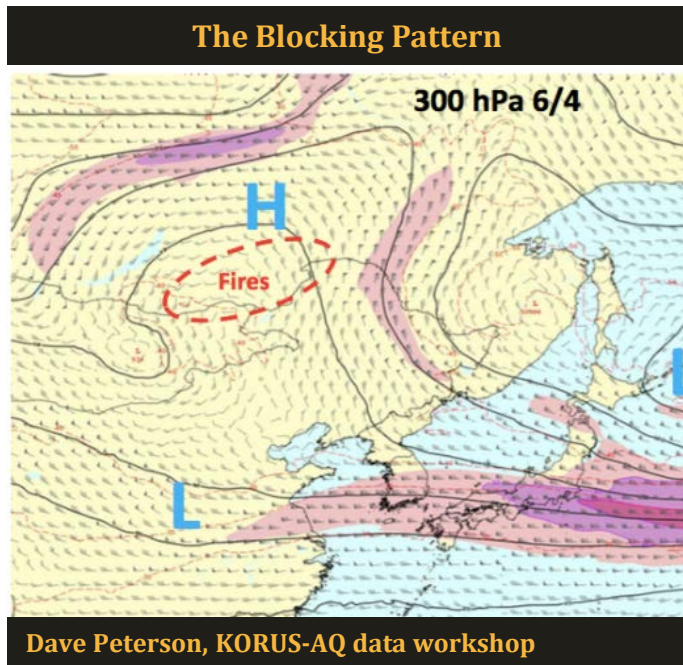
# PM<sub>2.5</sub> during the KORUS-AQ Campaign



# PM<sub>2.5</sub> during the KORUS-AQ Campaign

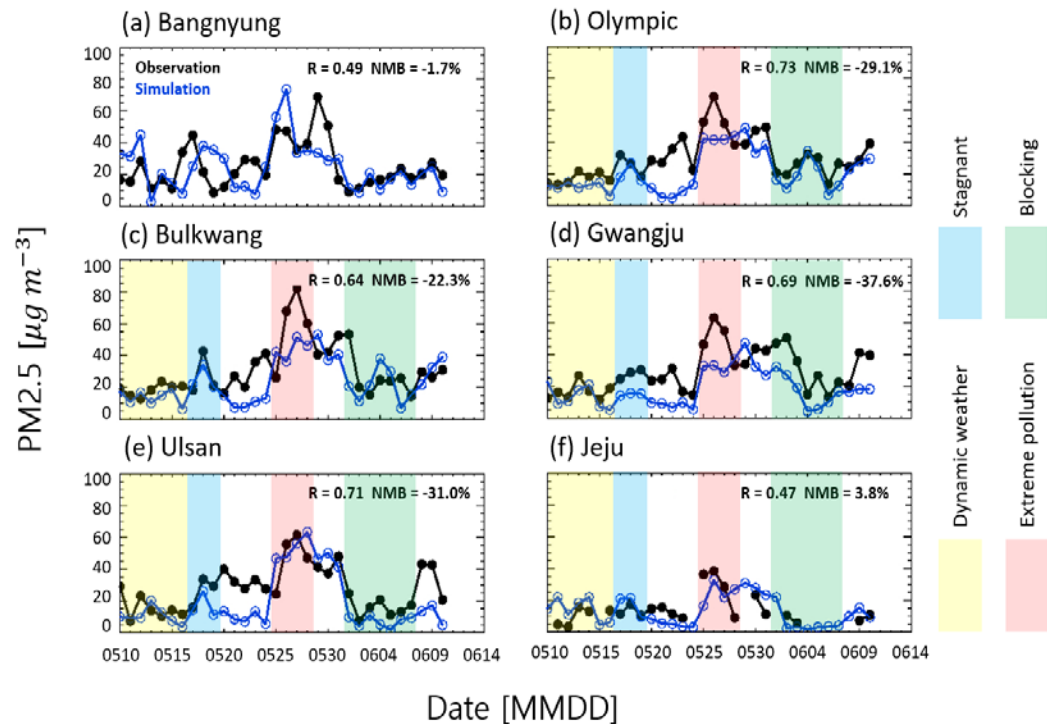
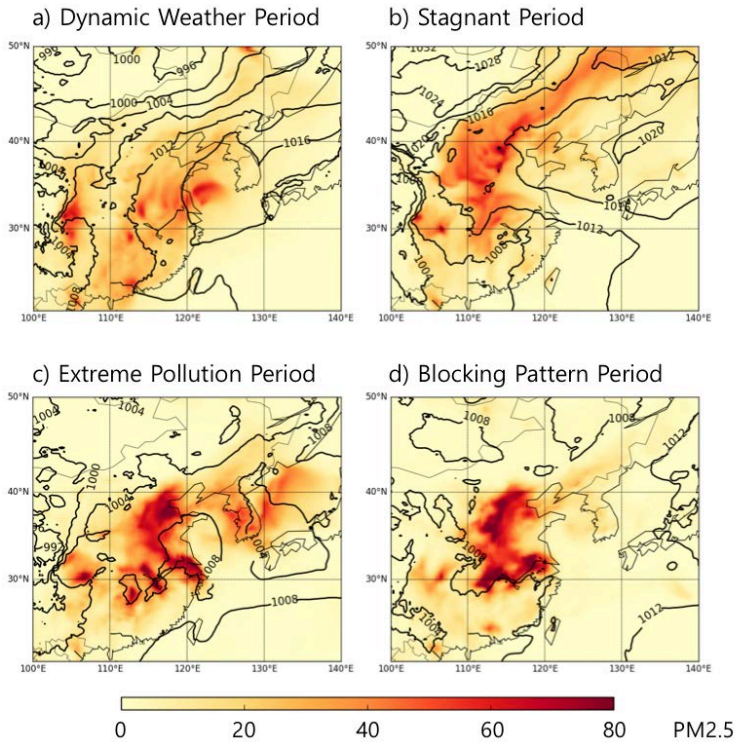


# PM<sub>2.5</sub> during the KORUS-AQ Campaign



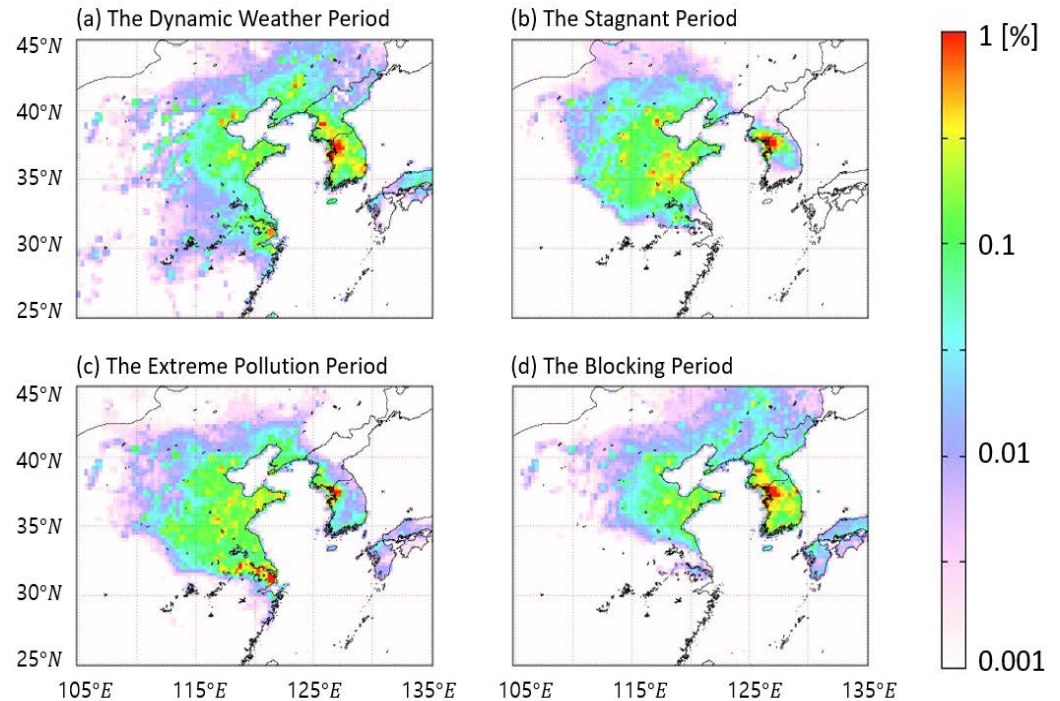
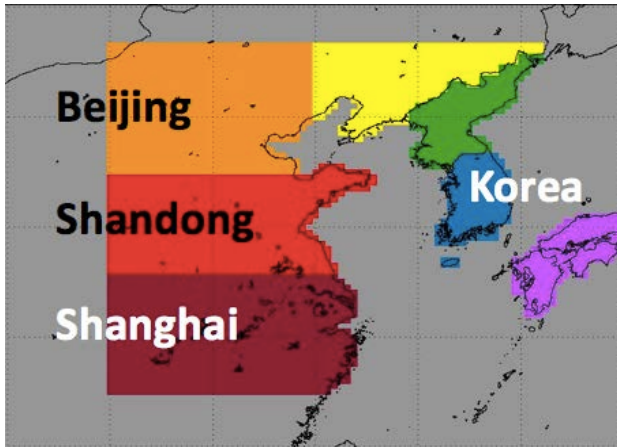
# Source Attribution by Adjoint Based Sensitivity Analysis

$$\frac{\partial [PM2.5]}{\partial E(x, t)}$$



# Regional Contributions by Periods

Regional Mask



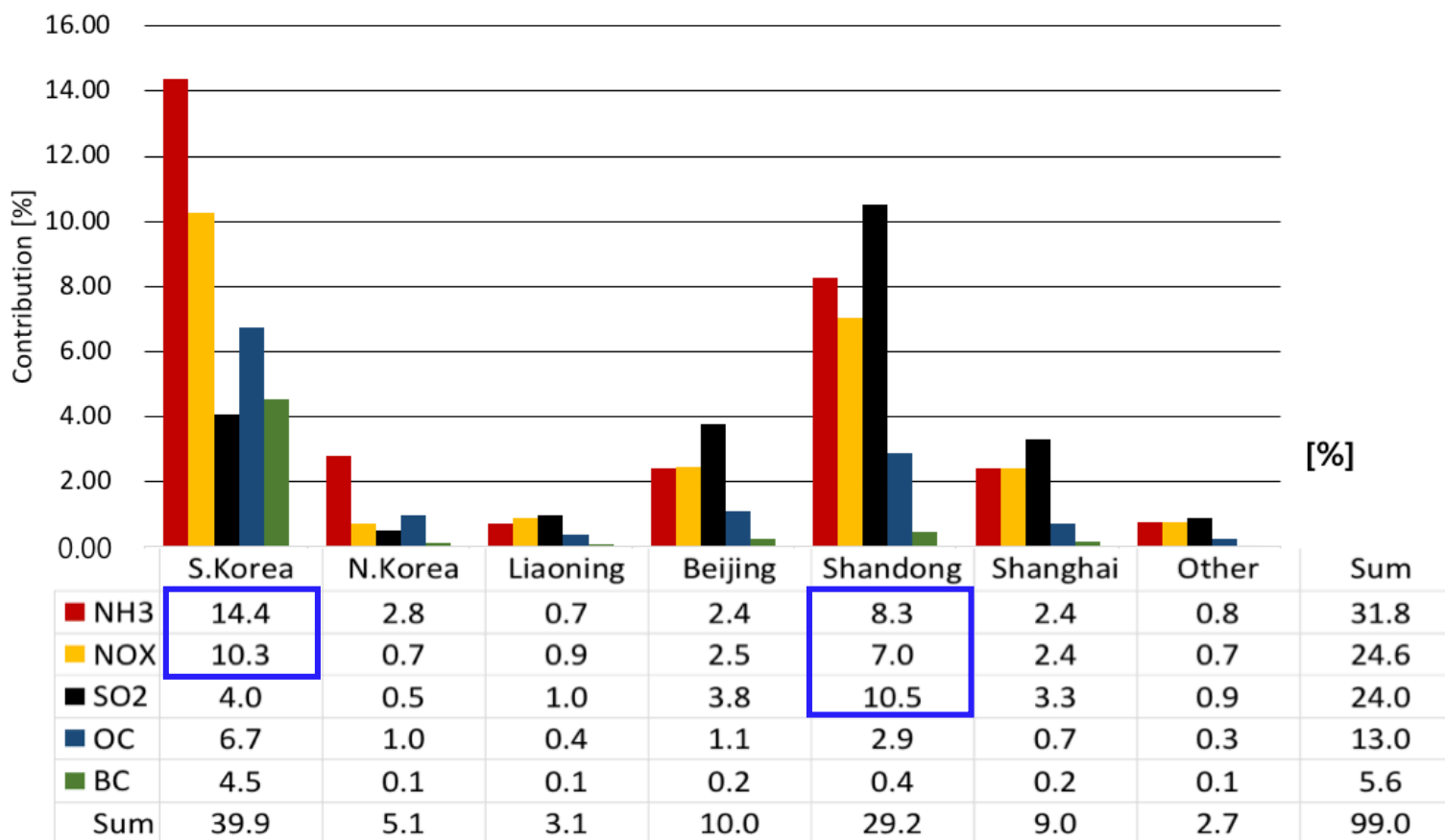
Regional Contributions [%]	Dynamic	Stagnant	Pollution	Blocking
South Korea	<b>50</b>	34	<b>26</b>	<b>57</b>
Beijing Region	<b>9</b>	16	<b>10</b>	<b>6</b>
Shandong Region	<b>17</b>	39	<b>38</b>	<b>17</b>
Shanghai Region	<b>6</b>	2	<b>18</b>	<b>~0</b>

Summary statistics from the table:

- South Korea: 50% (Dynamic), 57% (Blocking)
- Beijing Region: 9% (Dynamic), 16% (Stagnant), 10% (Pollution), 6% (Blocking)
- Shandong Region: 17% (Dynamic), 39% (Stagnant), 38% (Pollution), 17% (Blocking)
- Shanghai Region: 6% (Dynamic), 2% (Stagnant), 18% (Pollution), ~0% (Blocking)

# Which sources should be targeted for reduction?

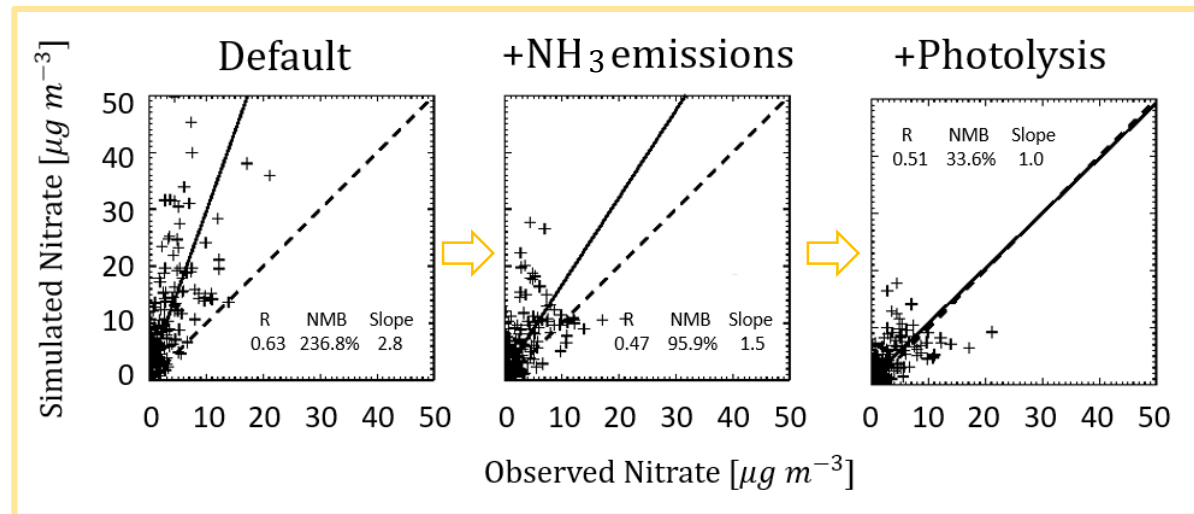
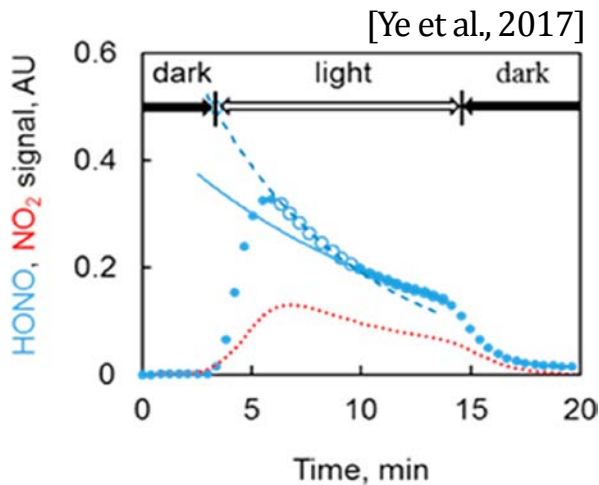
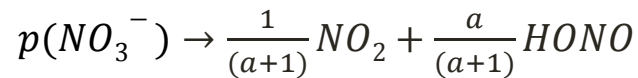
Contributions of emissions from each region/species to population exposure to PM2.5 in Korea during the KORUS-AQ



Thank you

# Updates to Resolve the Nitrate Overestimation

1. Diurnal variation in  $\text{NH}_3$  emission [Poulain et al., 2011; Zhu et al., 2015]
2. Additional Loss of  $\text{NO}_3^-$  by photolysis [Ye et al., 2017; Lee et al., in prep.]

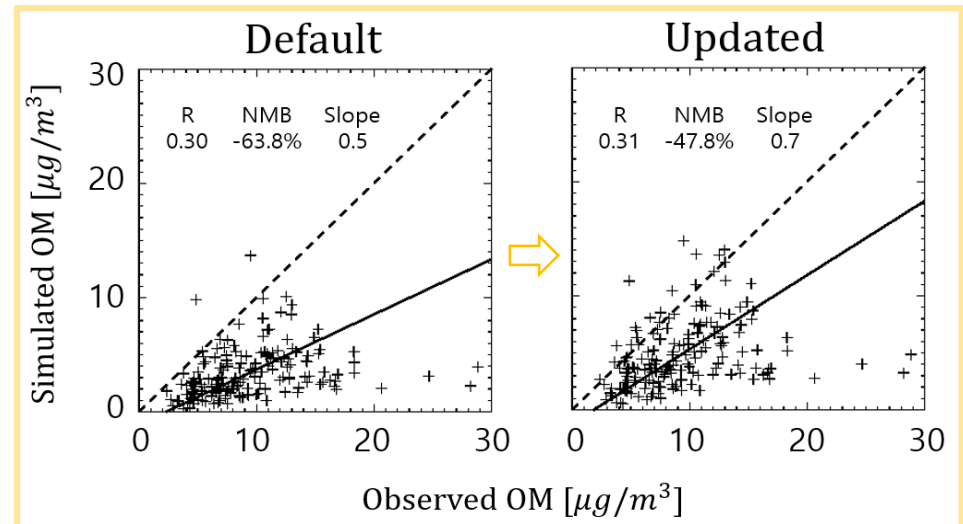


# Updates to Resolve the OM Underestimation

1. SOA formation from anthropogenic aromatics oxidation (benzene, toluene, xylene) [Henze et al., 2008]
2. Yields( $\gamma$ ) are from simulation with VBS approach [Jo et al., 2013]

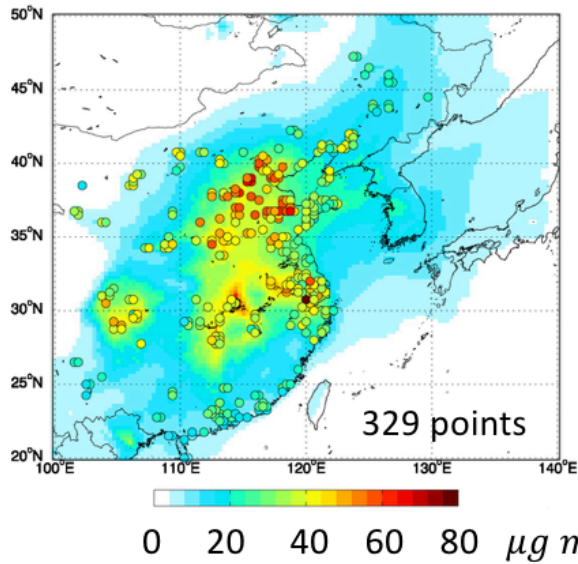
$$\gamma = \frac{SOA}{SOA + SOG}$$

$\gamma$  : aerosol fraction of aromatic SOA from the GEOS-Chem simulation considering the VBS approach with chemical aging

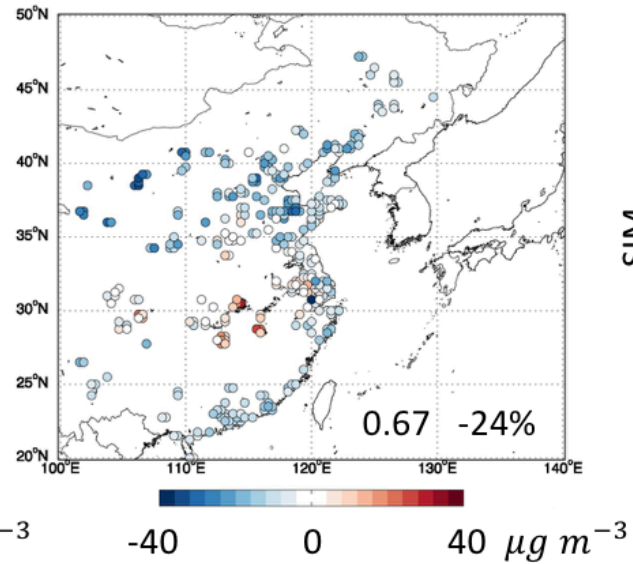


# Model Evaluation with Chinese measurements

KORUS-AQ



SIM - OBS



SIM vs. OBS

