Evaluating the efficacy of autumn-winter emission controls in the Beijing-Tianjin-Hebei region

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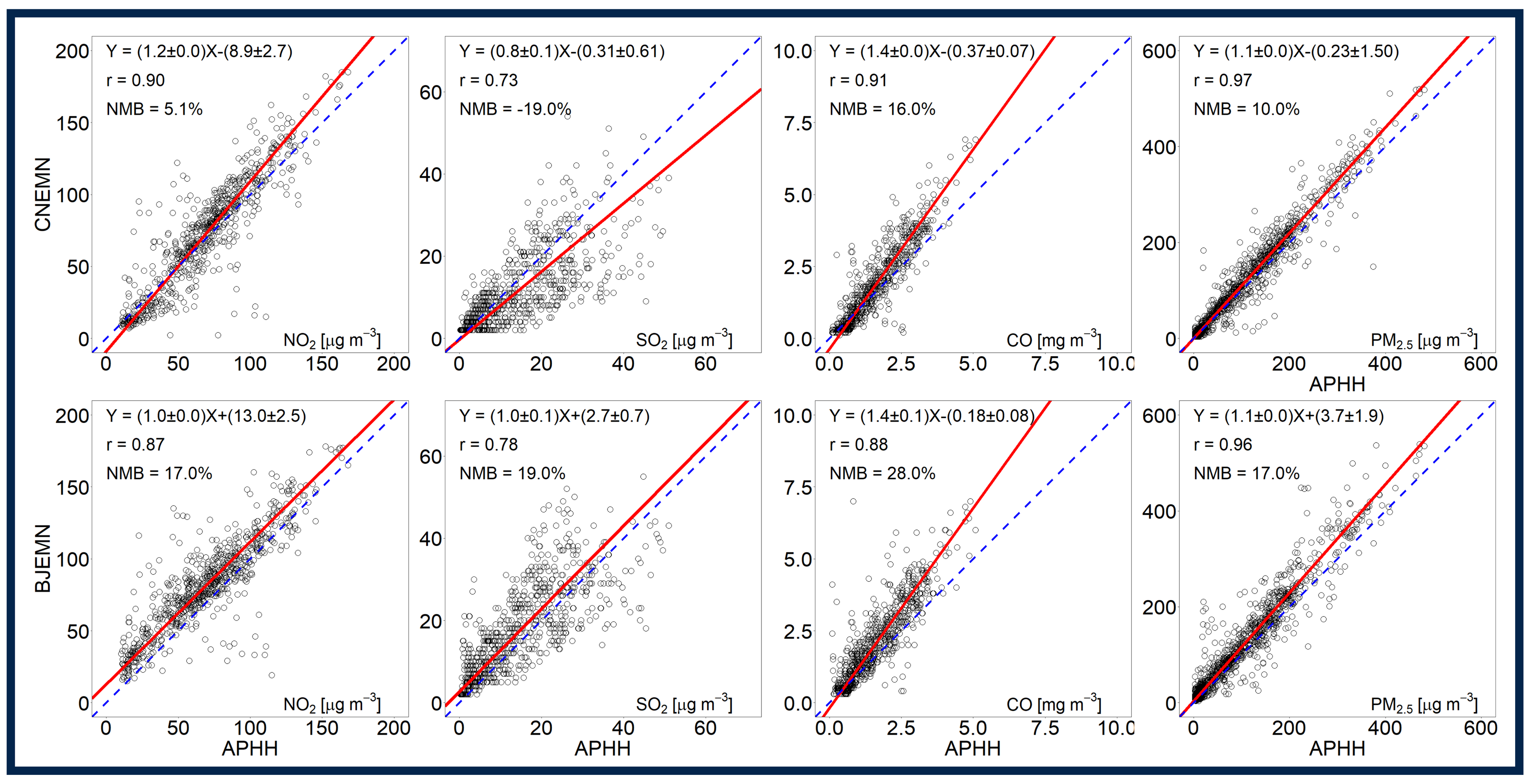
Introduction

The Beijing-Tianjin-Hebei (BTH) region experiences severely degraded air quality in autumn-winter due to anthropogenic emissions from various sources. Strict emission reductions were imposed in 28 ("2+26") cities in autumn-winter 2017-2018 (AW2017) to meet a 10-25% $PM_{2.5}$ reduction target relative to autumn-winter 2017-2016 (AW2016).

Here we use surface observations of air pollutants from surface air quality monitoring networks in China and the GEOS-Chem model to assess the efficacy of these short-term pollution controls.

Validation of Surface Air Quality Monitoring Networks in China

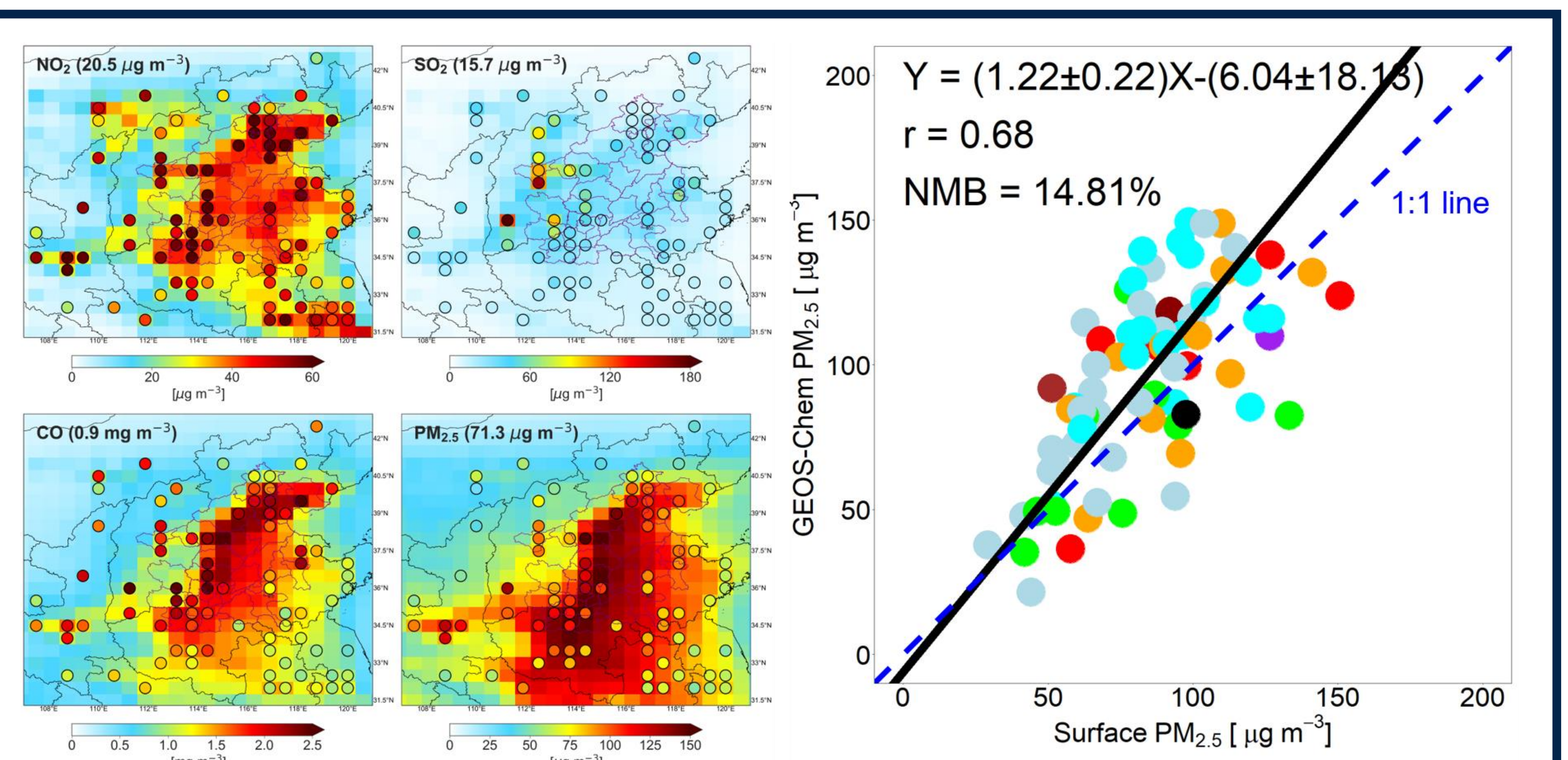
Comparisons of hourly measurements from APHH field campaign and the closest (~2.5 km) surface air quality monitoring network sites



Hourly observations of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and fine particulate matter ($PM_{2.5}$) from China National Environmental Monitoring Network (CNEMN) and Beijing Municipal Environmental Monitoring Network (BJMEMN) are consistent with measurements from the Atmospheric Pollution & Human Health (APHH) China programme in November-December 2016 (r > 0.7 for gaseous air pollutants; r > 0.95 for $PM_{2.5}$).

GEOS-Chem Simulated Surface Air Pollutions

Comparisons of GEOS-Chem with surface observations in BTH and its surrounding areas in AW2016



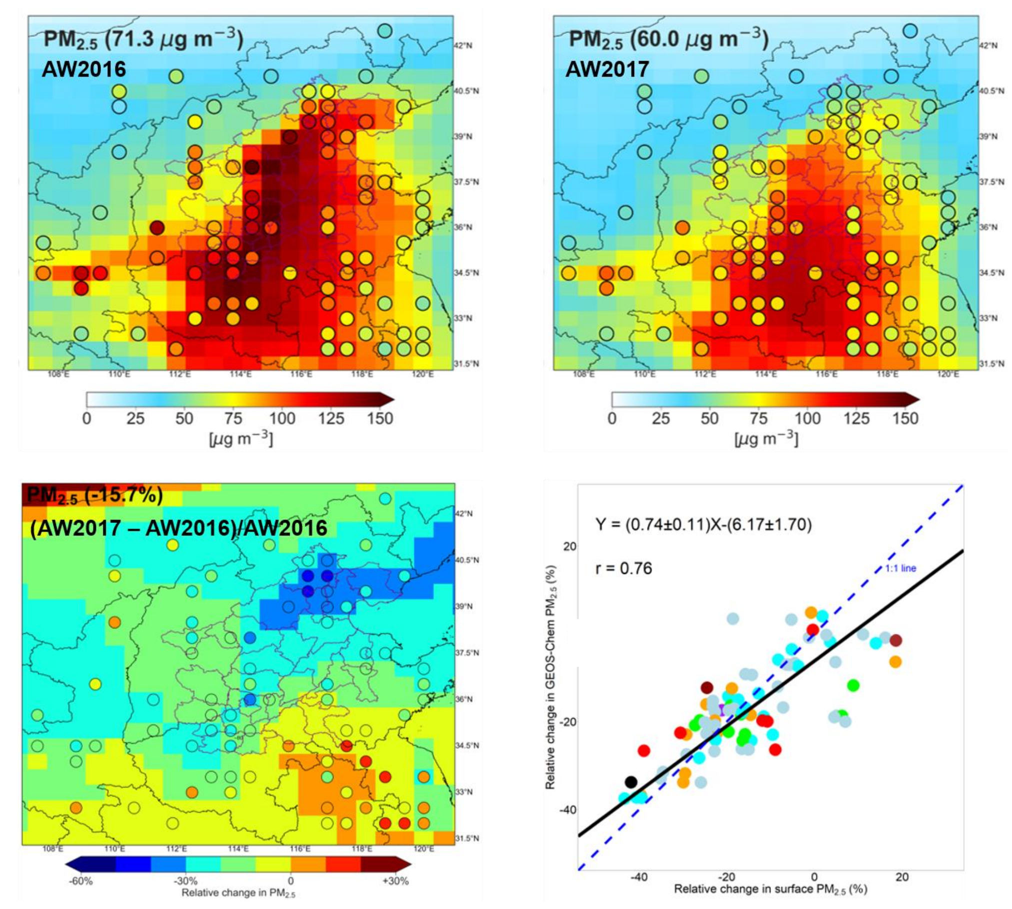
Inset text: domain mean from GEOS-Chem model

GEOS-Chem version: 12.0.0 (with updated wet scavenging scheme)
Meteorology: MERRA-2 (0.5° × 0.625° resolution with 47-layers)
Emission inventory: Multi-resolution Emission Inventory (MEIC)
Time: AW2016 (Oct 2016 - Mar 2017) & AW2017 (Oct 2017 - Mar 2018)

GEOS-Chem is used to estimate surface concentrations of $PM_{2.5}$ and its precursors in AW2016 and AW2017. The model (grids) well reproduced observed surface $PM_{2.5}$ (circles) in BTH and its surrounding area in AW2016 when the emission controls were not implemented (slope = 1.22, intercept = -6.04 μg m^{-3}, r = 0.68, NMB = 14.81%).

Relative Changes in Observed and Simulated Surface $PM_{2.5}$

Relative changes in surface $PM_{2.5}$ in AW2017 compared to AW2016

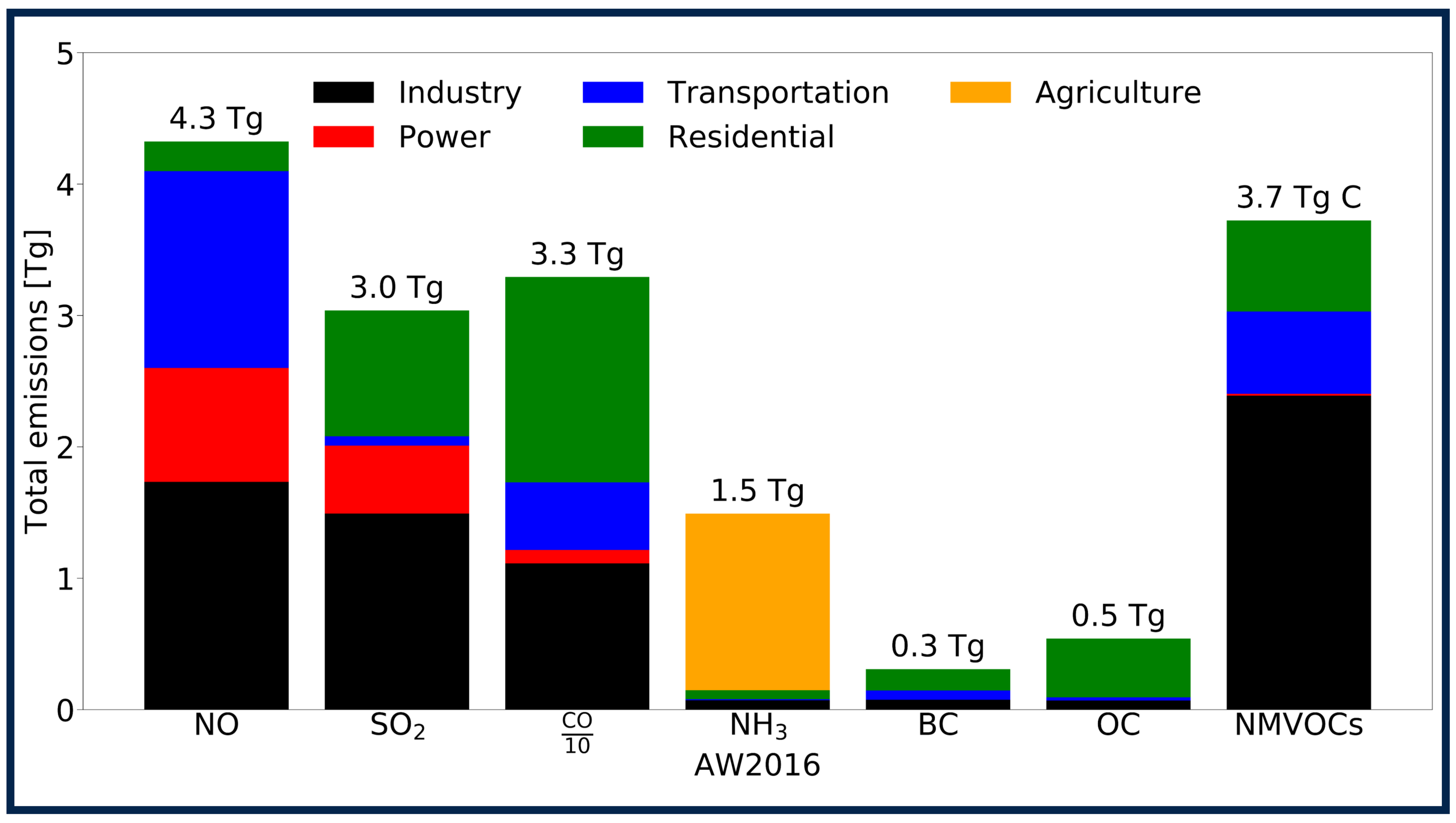


Inset text: domain mean from GEOS-Chem model

The surface monitoring sites (circles) observes a domain mean decrease in $PM_{2.5}$ of 14.9% in AW2017, with 3.0%, 28.5% and 17.4% for NO_2, SO_2 and CO, respectively. The GEOS-Chem model also shows similar reductions of $PM_{2.5}$ (15.7%) in the domain. But it underestimates the magnitudes of relative changes in $PM_{2.5}$ (slope = 0.74) while it well reproduces observed $PM_{2.5}$ in AW2016.

Anthropogenic emissions from MEIC

Total anthropogenic emissions of NO, SO_2, CO, NH_3, BC, OC and NMVOCs in North China Plain in AW2016



Scale factors are applied to MEIC emissions based on the discrepancies in surface concentrations from the measurements and the model with the original MEIC inventory. These include a uniform scale factor of 1.5 applied to MEIC NO emissions and of 2.4 to MEIC CO emissions across the domain. Spatially varying scale factors are applied to MEIC SO_2, as just 7 grids in the model are responsible for a 41% underestimate in modelled SO_2 concentrations.

Next Steps:

- Compare $PM_{2.5}$ components with APHH campaign measurements and literature.
- Conduct model experiments to investigate sensitivity of $PM_{2.5}$ to interannual variations in meteorological conditions.

Data Sources

Surface data from CNEMN and BJMEMN: https://beijingair.sinaapp.com/
APHH campaign measurements:
https://catalogue.ceda.ac.uk/uuid/648246d2bdc7460b8159a8f9daee7844