Applying the SOSAA Atmospheric Chemistry Model to Air Quality Analysis:

A Case Study of a Severe Air Pollution Episode in November 2018 in Beijing, China

We successfully modelled pollutants in Beijing during this severe air pollution episode.

- **Clean days before & after episode → Model performed very well** 😀
- **Pollution episode → Model performed moderately well** 🤔
- **Cold front → Well captured in model** 😀

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What's the problem?

Recurring severe air pollution episodes cause health problems and economic damage.

What is this project about?

Applying a column model to follow the path of air arriving at a measurement station in Beijing during a pollution episode.

What does the model do?

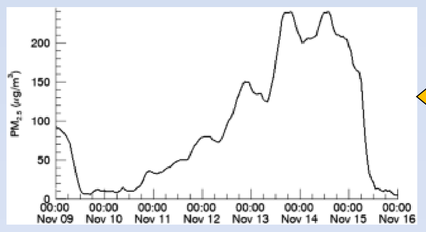
Takes in emissions along the path leading up to the station and calculates chemistry of gases and aerosol formation.

How can the results be used?

Help us understand chemical reactions and processes before and during these episodes. This can help us make decisions to prevent such episodes in the future.

Introduction

Every year, Beijing and the surrounding region experiences severe air pollution episodes, which have serious consequences on human health and cause economic losses (Luo et al., 2021; Gao et al., 2015; Ji et al., 2012; Jiang et al., 2015). This study focuses on modelling an episode that affected Beijing from 9-15 November 2018.

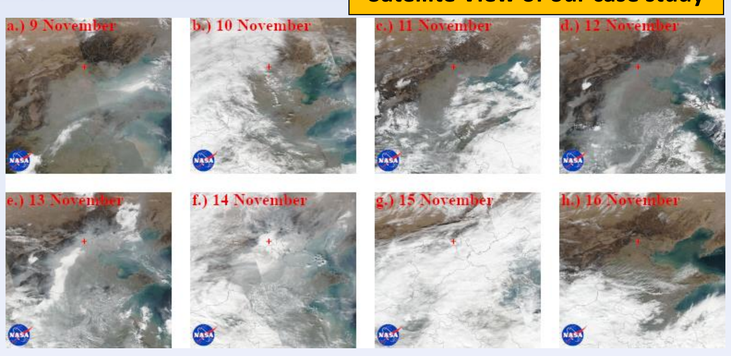


Case study pollution episode

Figure 1: Average of $PM_{2.5}$ concentrations from 35 stations throughout Beijing during a severe air pollution episode in November 2018.

This episode followed a typical pattern during autumn and winter in Beijing, which includes a slow buildup over several days, followed by rapid cessation resulting from a synoptic weather feature, usually a cold front (Zheng et al. 2016).

Satellite View of our case study



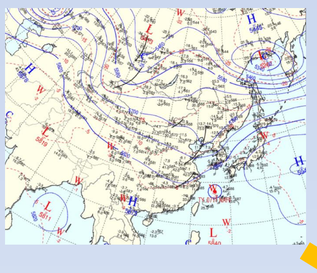
Imagery downloaded from NASA Earthdata, open-access database.

Figure 2: Visible satellite imagery over northeastern China from the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi-NPP satellite: a.) 9 November as the previous pollution episode is subsiding; b.) 10 November, in the early stages of the episode. Beijing, noted by the red cross, is obscured by clouds; c.) 11 November as the episode is gradually building up; d.) 12 November as the episode is continuing to accumulate; e.) 13 November as the episode is reaching its peak; f.) 14 November when haze and clouds become indistinguishable; g.) 15 November when clouds are obscuring the region; h.) 16 November, after the pollution episode has subsided and the air appears clean. Each image was captured between 12:30 and 14:00 local time.

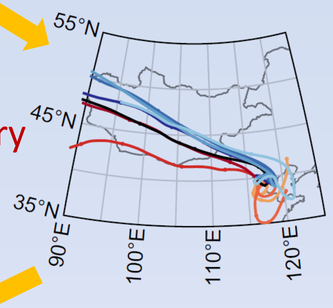
In this study, we applied the model to Simulate the concentration of Organic vapors, Sulfuric Acid, and Aerosols (SOSAA) to this episode. SOSAA is a column model of atmospheric chemistry and aerosol formation, and for this study, it follows a backward trajectory, taking in emissions and meteorology data leading up to the site of interest. The site is at the Beijing University of Chemical Technology's Aerosol and Haze Laboratory (BUCT-AHL), a research station built in cooperation with BUCT and University of Helsinki.

Results of this study can help understand the behavior of such episodes and help predict, prevent, and mitigate them in the future. This can be useful for forecasters, health officials, policy makers, economists, and scientists.

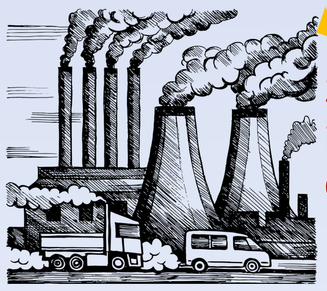
Methods



1. NWP input
   - ECMWF-ERA5
   - NCEP-GFS-FNL

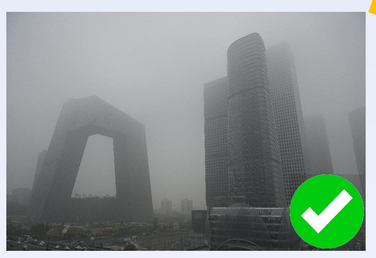


2. FLEXPART trajectories, every 3 hours



3. Emissions inventory from CAMS

4. Chemistry and aerosol formation modelled by SOSAA



5. Evaluation against measurements

Figure 3: Diagram of our modelling system. Starting with numerical weather forecast (NWP), the model takes meteorological information, used to calculate trajectories and atmospheric processes. We will compare ERA5, GFS, and Enviro-HIRLAM. Trajectories were calculated with the FLEXPART model. Emissions is from CAMS and is used by SOSAA for calculating the atmospheric processes.

What is the future of this project?

- Run with Enviro-HIRLAM NWP+ACT model, which includes aerosol effects.
- Run with new aerosol and chemistry schemes.
- Use higher-resolution China-based emissions inventory for runs.
- Scenario analyses.
- Identify likely causes of severe pollution episodes and propose potential solutions.
- Parameterizing pollution episodes in climate models.
- Perform same analysis in Istanbul, Turkey

Note: References can be found in the online version of this poster (using the QR code above).

Results & Discussion

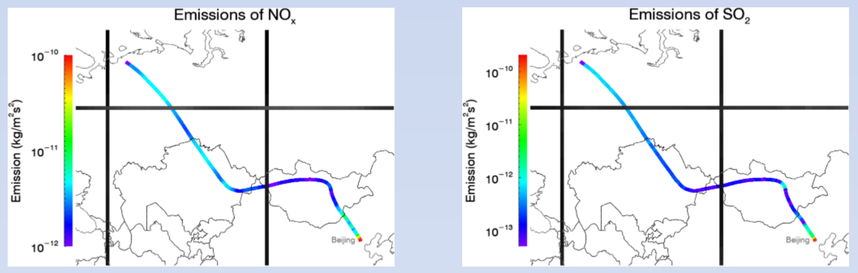


Figure 4: Footprint of NO_x and SO_2 emission ending in Beijing at 12:00 UTC (20:00 local time) on 9 November 2018. This map shows the average trajectory (generated by FLEXPART using ERA5), but note this is not the full footprint. Emission data is from CAMS.

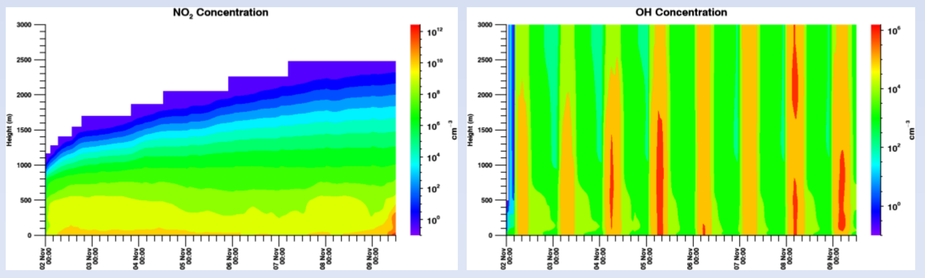


Figure 5: Concentrations of NO2 and OH modelled by SOSAA along the same footprint as in Figure 4.

Output from SOSAA

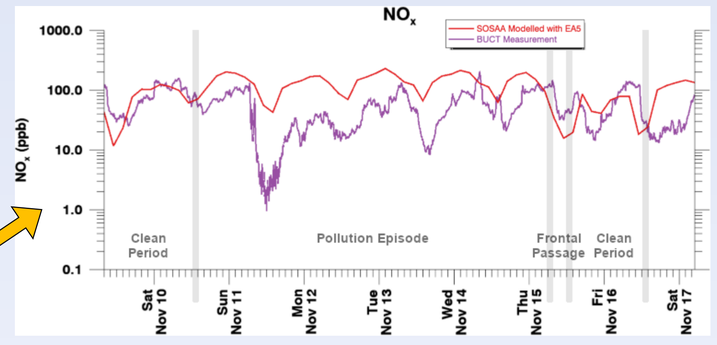


Figure 6: An example of SOSAA output, showing concentrations of NOx at BUCT before the episode, during the episode, during frontal passage, and after the episode. The model performs very well during the cold front and clean period and performs moderately well during the pollution episode.

The next step in this project is to use online integrated Environment-High Resolution Limited Area Model (Enviro-HIRLAM; Baklanov et al., 2017) as an alternative, which takes into account aerosol effects when calculating meteorological parameters – this may be particularly useful when heavy aerosols during pollution episodes create localized feedback on temperature and atmospheric conditions.

Additionally, we plan to use higher-resolution, China-specific emissions inventories for future model simulations.

Then we would like to run scenerio analyses, e.g. switching cars to electric, to test what factors may improve air quality during episodes of extremely unhealthy air. This will help us understand the causes and potential solutions to these episodes.

Because these episodes are often very widespread (as shown in Figure 2), air pollution episodes can affect aerosol-climate interactions and climate radiative forcing (Baklanov et al. 2016). Results of this project could be used to parameterize pollution episodes in climate models.