Using MAX-DOAS observations to evaluate GEOS-Chem over Central London

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1. Motivation

- London is a megacity with severe air quality issues. An understanding of how weather events and policy changes effect air quality is required to protect public health.
- The UCL Multi Axis Differential Absorption Spectroscopy (MAX-DOAS) instrument is used to evaluate GEOS-Chem over the city and assess the current understanding of the factors influencing air quality in London.

2. The UCL MAX-DOAS

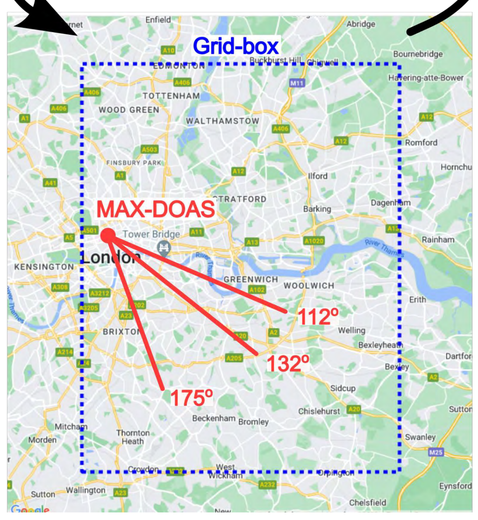
- The instrument measures spectra over elevation angles -1°, 1°, 2°, 3°, 5°, 10°, 20°, 40°, and 90°.
- Three azimuth angles (112°, 132° and 175°) scan southeast of London between buildings. Objects on the roof obscure the northerly region.
- The instrument detects UV-Vis active atmospheric species.
- Vertical profiles of HCHO and NO_2 obtained with the RAPDOSI retrieval algorithm have been used to characterize ozone production in London for summer 2022.[1]

Evaluate

A priori

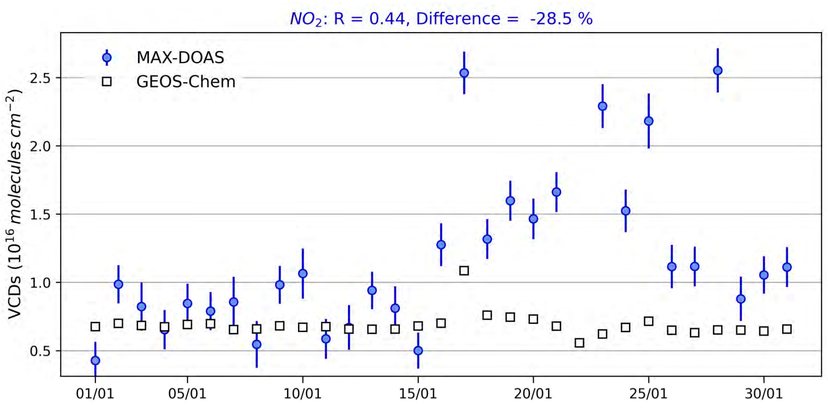
3. GEOS-Chem

- We use GEOS-Chem nested grid simulations $(0.25° \times 0.3125°)$ centered over Greater London $(49.25°N - 59.5°N, 9.375°W - 3.75°E)$ as the a priori for the retrieval of MAX-DOAS vertical profiles.[1]
- Model inputs are NASA GEOS-FP assimilated meteorology and anthropogenic emissions from the Community Emissions Data System version 2.
- MAX-DOAS retrievals with degrees of freedom < 1 are removed.
- MAX-DOAS averaging kernels are used to smooth GEOS-Chem vertical profiles.



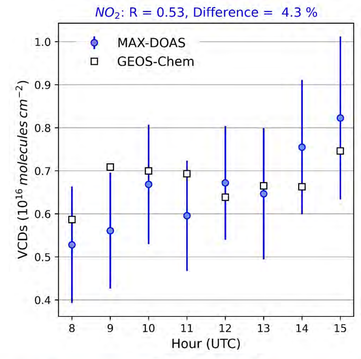
4. January 2023

- GEOS-Chem generally underestimates **NO_2**.
- MAX-DOAS observations in January exhibit a peak in **NO_2** between 17 and 25 where concentrations increased by **69 %**.

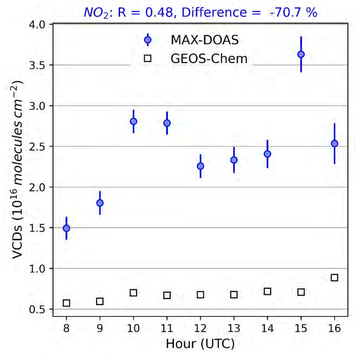


- High pressure, no rain and low temperatures caused pollution to accumulate in London.[2]

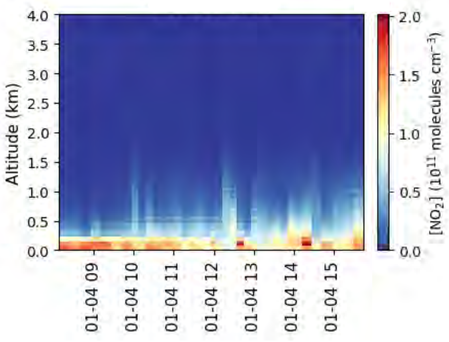
4 January

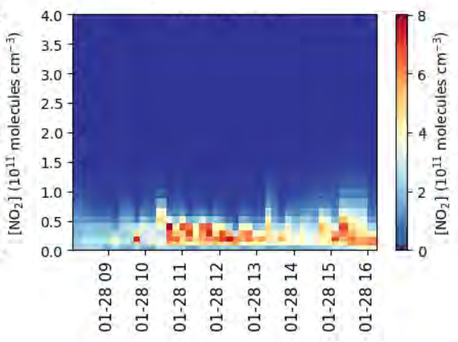


28 January



- Vertical column densities and vertical profiles for days with the best (4 January) and worse (28 January) agreement between the model and instrument for **NO_2**.
- GEOS-Chem typically underestimates diurnal variations in **NO_2**.

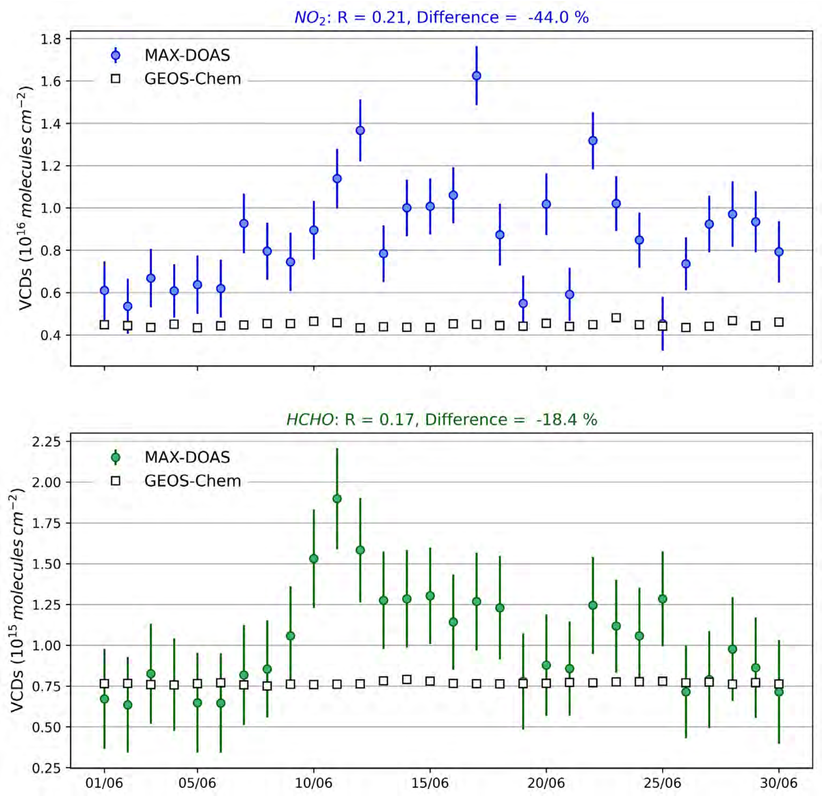




- When **NO_2** concentrations increase due to the January pollution event, the model fails.

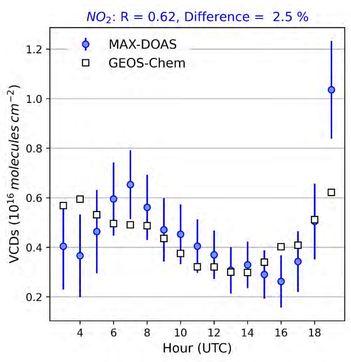
5. June 2023

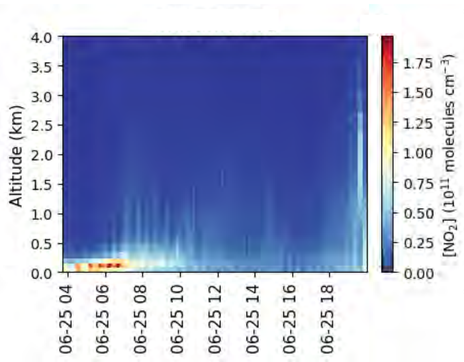
- GEOS-Chem generally underestimates both **NO_2** and **HCHO**.
- MAX-DOAS observations in June display a peak in **NO_2** and **HCHO** between 9 and 17 where concentrations increased by **52 %** and **58 %** respectively.



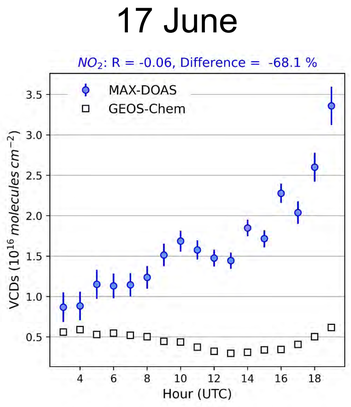
- High pressure, air flow from Europe, little rainfall and elevated temperatures trapped pollution in London.[3]

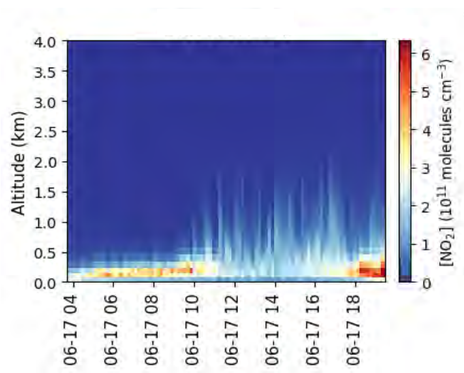
25 June





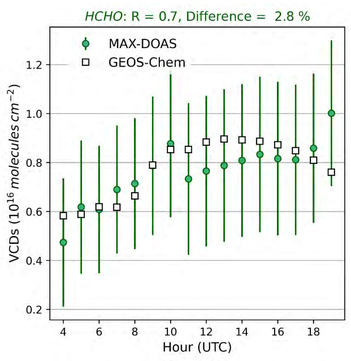
17 June

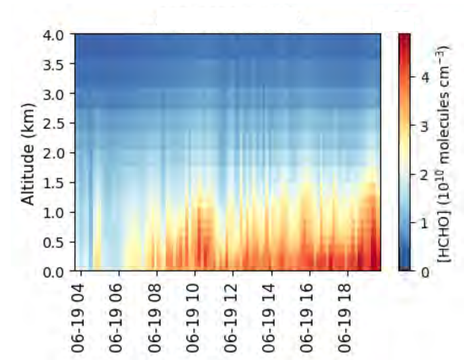




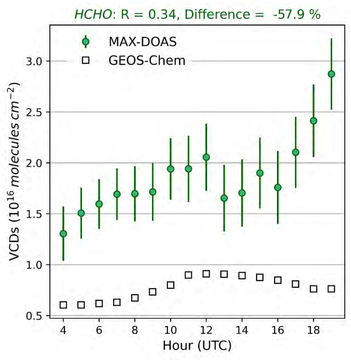
- Vertical column densities and vertical profiles for days with the best (25 June) and worse (17 June) agreement between the model and instrument for **NO_2**.
- GEOS-Chem typically underestimates diurnal variations in **NO_2**.
- When **NO_2** concentrations increase during the June pollution event, the model fails.

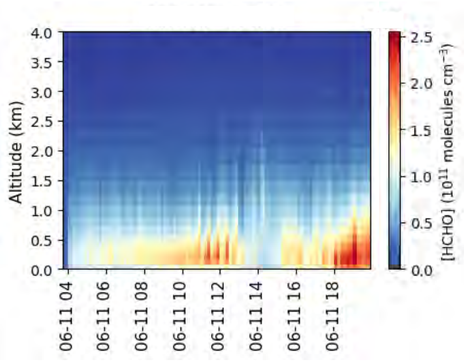
19 June





11 June





- Vertical column densities and vertical profiles for days with the best (19 June) and worse (11 June) agreement between the model and instrument for **HCHO**.
- GEOS-Chem underestimates diurnal variations in **HCHO**.
- When diurnal **HCHO** variability deviates from the norm, the model fails.
- The model does not reproduce day-to-day variability in emissions.
- GEOS-Chem does not reproduce pollution events.

6. Future Work

- Conduct lowest layer comparisons between the MAX-DOAS, GEOS-Chem and Bloomsbury and Marylebone surface monitoring sites.
- Use the European Monitoring and Evaluation Programme (EMEP) emission inventory in GEOS-Chem simulations.

References

1. R. G. Ryan, E. A. Marais, E. Gershenson-Smith, R. Ramsay, J.-P. Muller, J.-L. Tirpitz and U. Frieß, *Atmos. Chem. Phys.*, 2023, **23**, 7121–7139.
2. Met Office, January 2023 Climate Summary, 2023.
3. Met Office, June 2023 Climate Summary, 2023.