Modelling photochemical impacts of haze pollution in a Chinese Megacity

RMetS Air Pollution in Megacities: 20th March 2019

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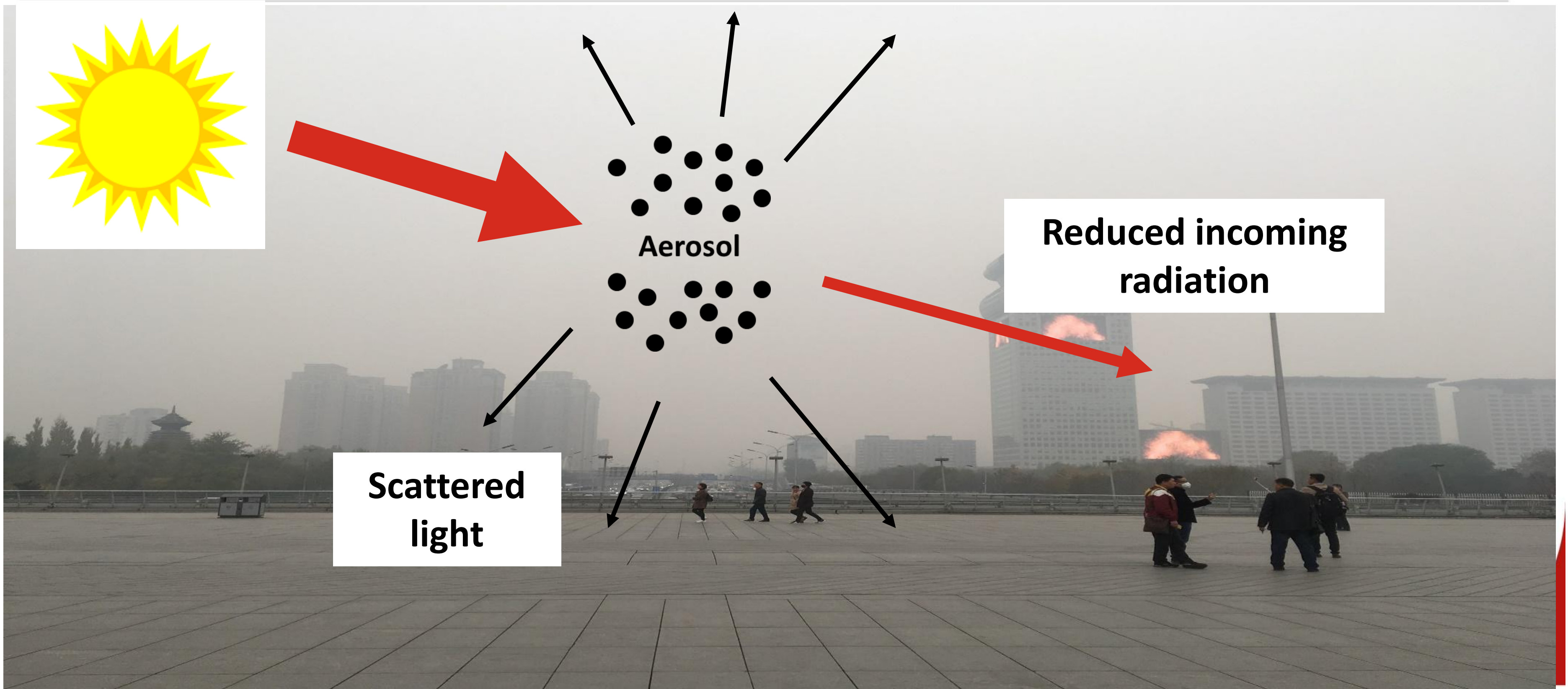
Air pollution in Beijing



Impacts of haze on photolysis

- Photolysis is a key driver of oxidant photochemistry through effect on species such as O_3 and NO_2
- HONO photolysis important source of OH in urban environments
- Aerosols in haze can impact photolysis rates
- Implications for both local and regional atmospheric chemistry. E.g. Secondary aerosol formation

FAST–JX photolysis scheme

- Simulates the multiple scattering of aerosol and cloud layers in the atmosphere

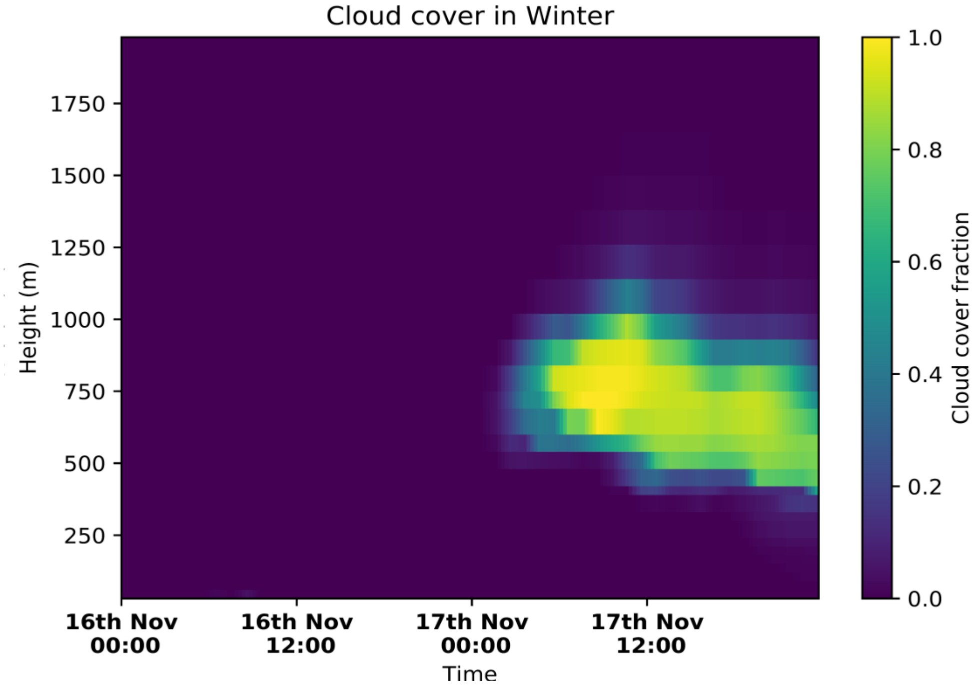
- Simulates photolysis rates for 18 wavelength bins covering both the troposphere and stratosphere

- Can be driven in stand-alone mode with observations/re-analysis data

- Is also integrated into a number of atmospheric models and fully coupled to model chemistry schemes (E.g. UKCA).

Simulation of photolysis rates in Beijing – modifications to FAST - JX

- Modified to include NO_2 absorption
- Scattering phase functions updated based on campaign measurements
- Account for effects of coating on absorption by Black Carbon (BC)
- Driven using cloud data from ECMWF ERA5 reanalysis data



Cloud Layers

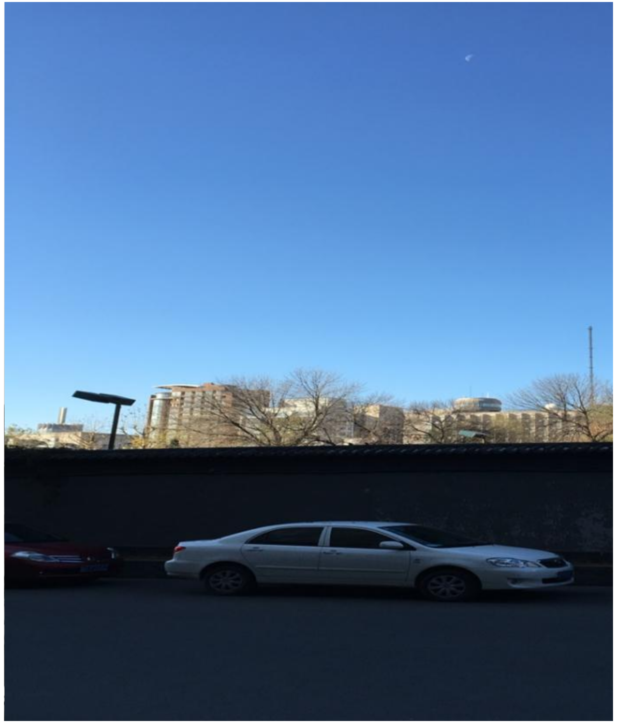
APHH campaigns: Nov-Dec 2016 & May-June 2017

- Aerosol composition and size monitored throughout both campaigns

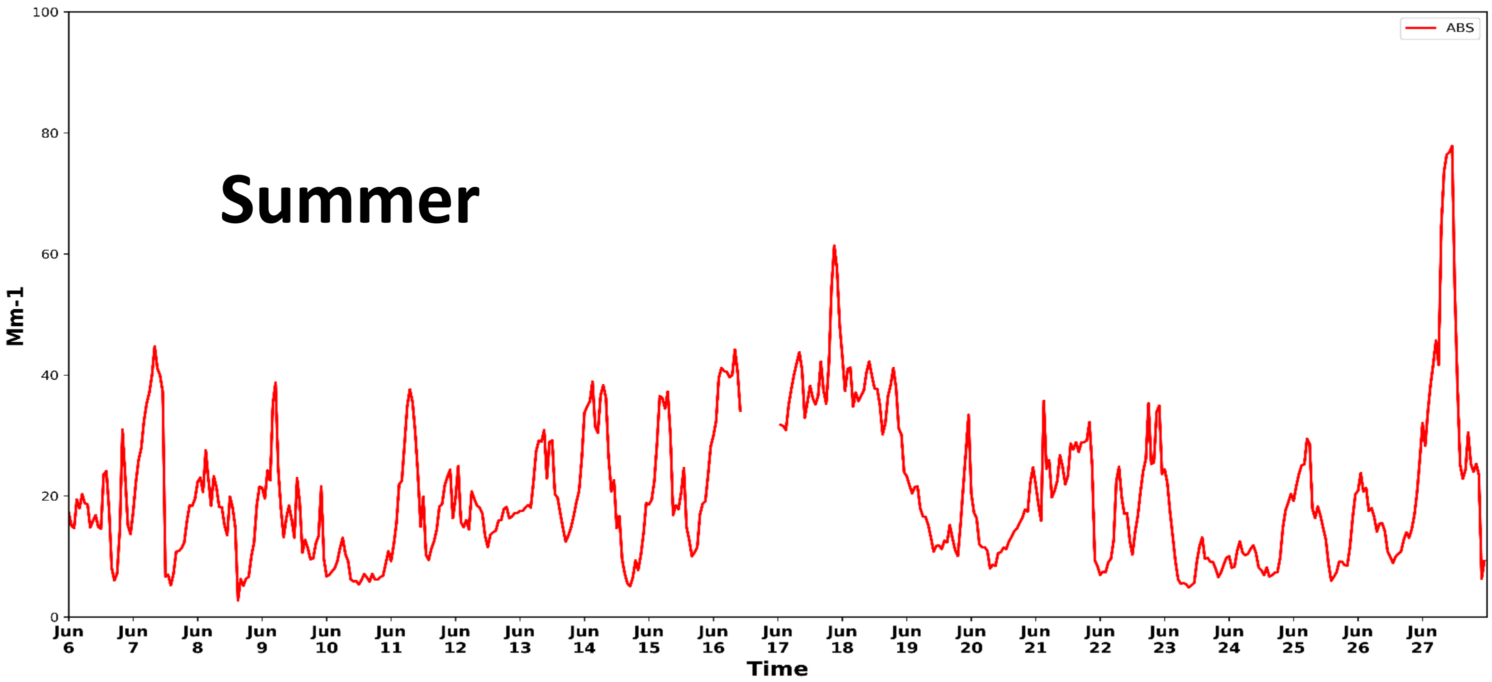
- Lidar extinction by aerosol to show vertical distribution of aerosol layers

- Co-located PAX instrument to measure total aerosol extinction at the surface

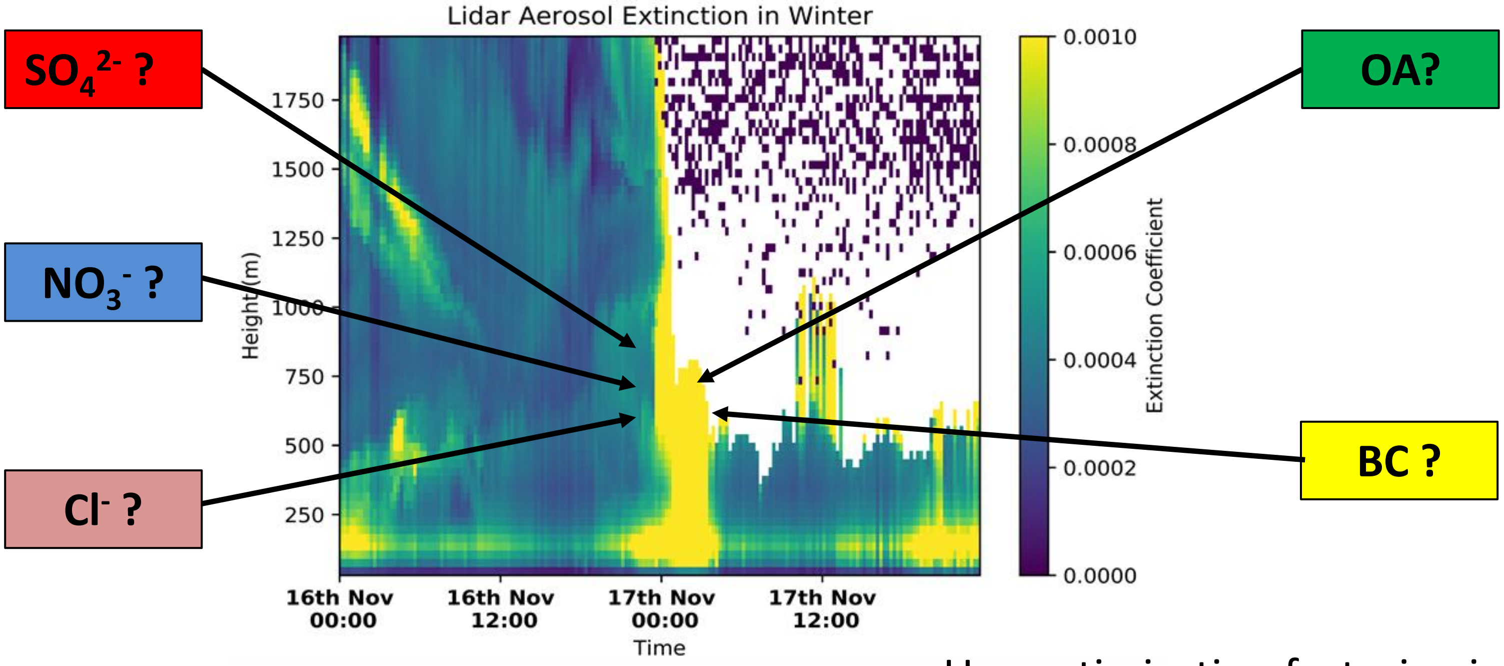
- SP2 instrument to measure BC properties including core and coating size



Measured aerosol extinction during both campaigns.



How do we estimate vertical profiles of each aerosol species?

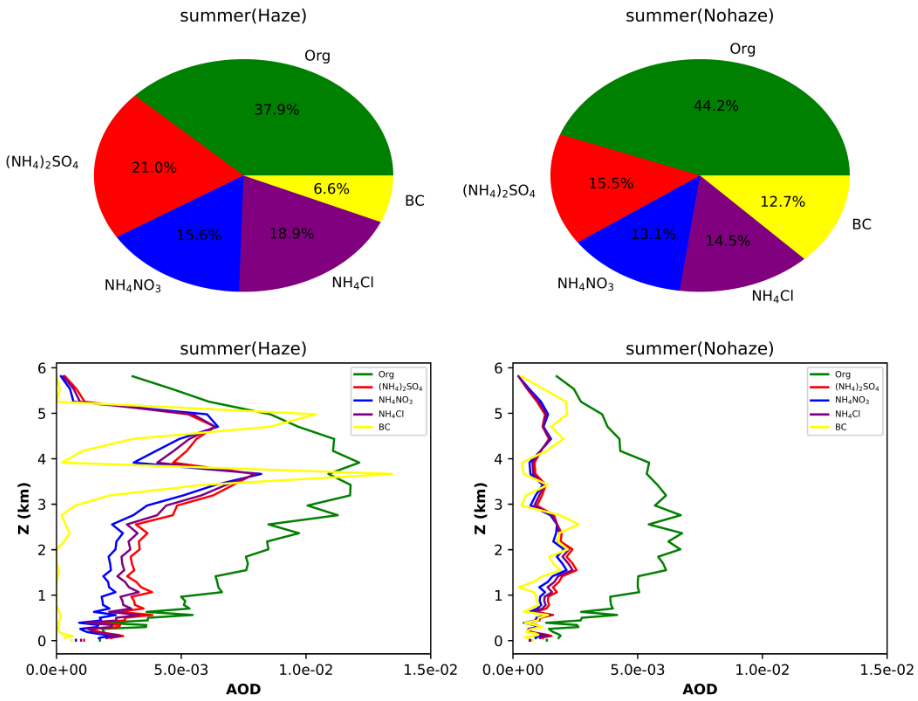


Aerosol Layers

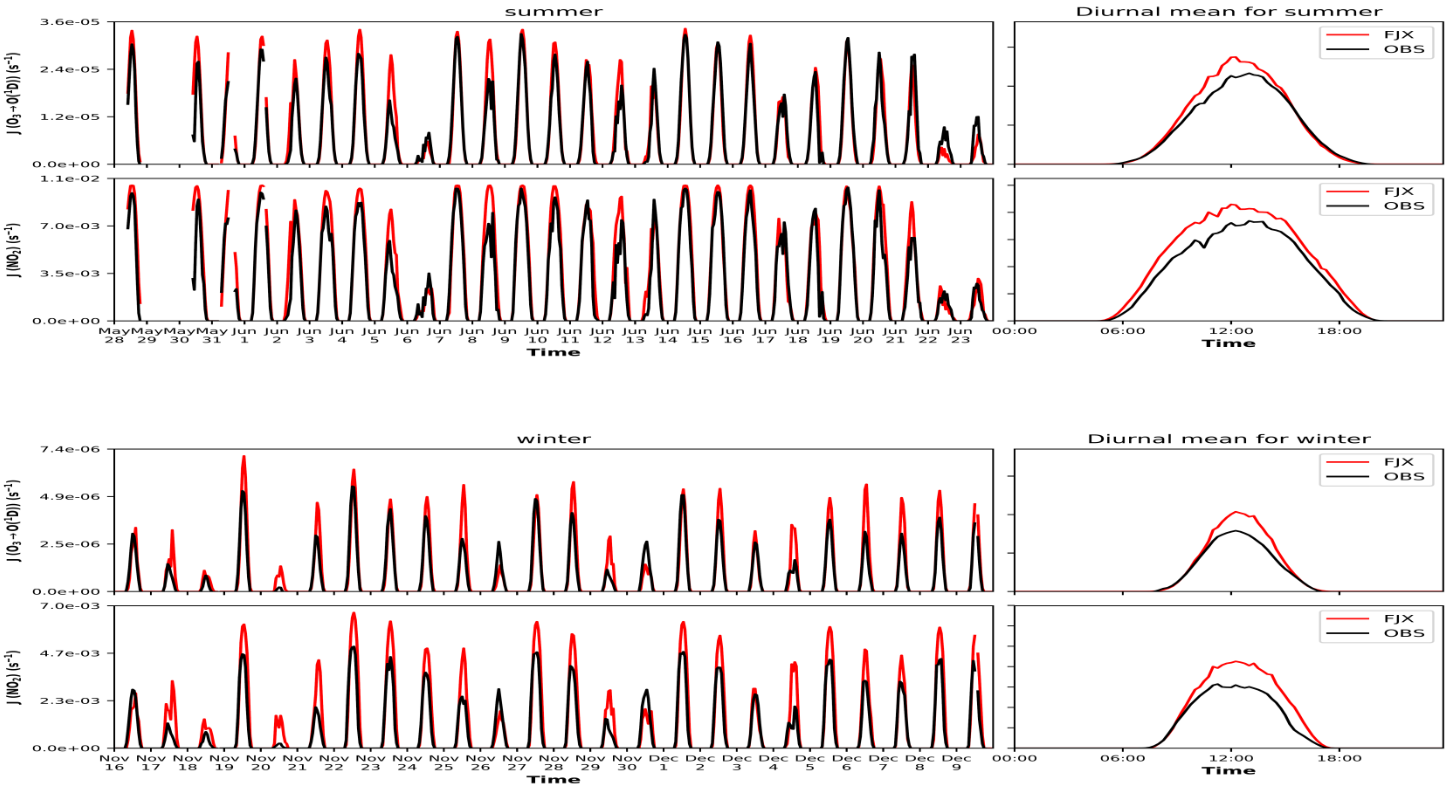
Use optimisation factoring in hygroscopic growth

Which aerosols contribute the most to AOD?

- Haze days: $PM_{2.5}$ > 75 μgm^{-3} (AQI 100)
- SO_4 and BC dominate winter haze
- Organic aerosol dominate summer haze
- Largest AOD tend to be higher altitudes in summer – regional transport?

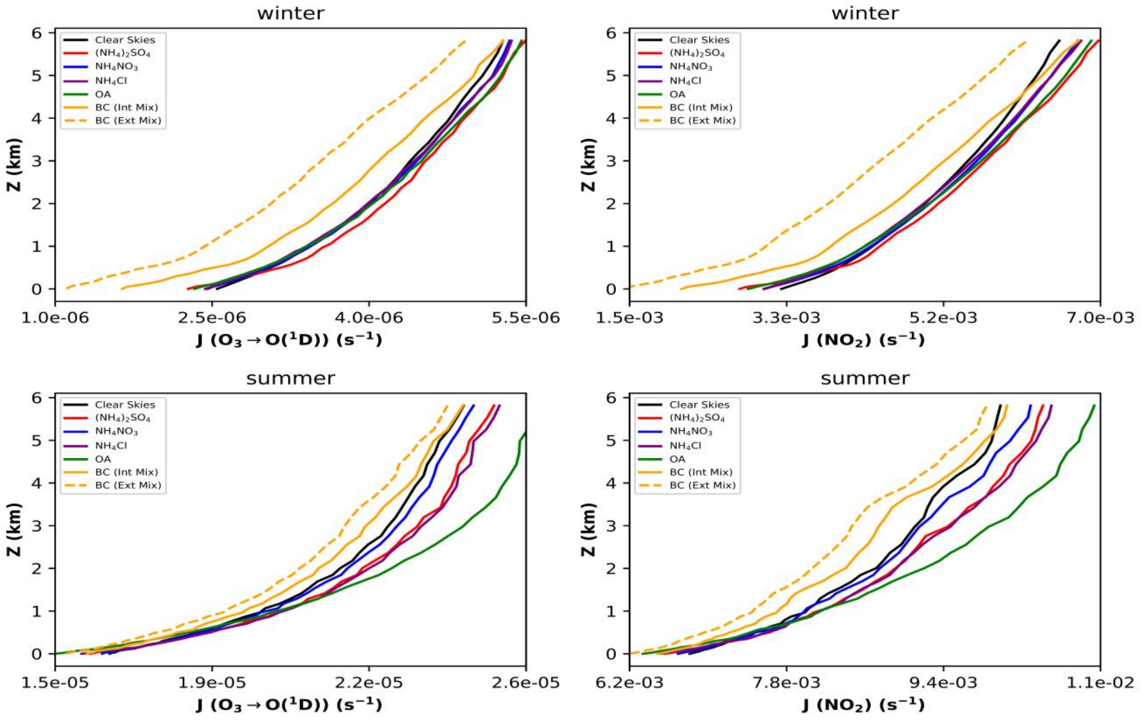


How well does FAST-JX capture haze events over Beijing?



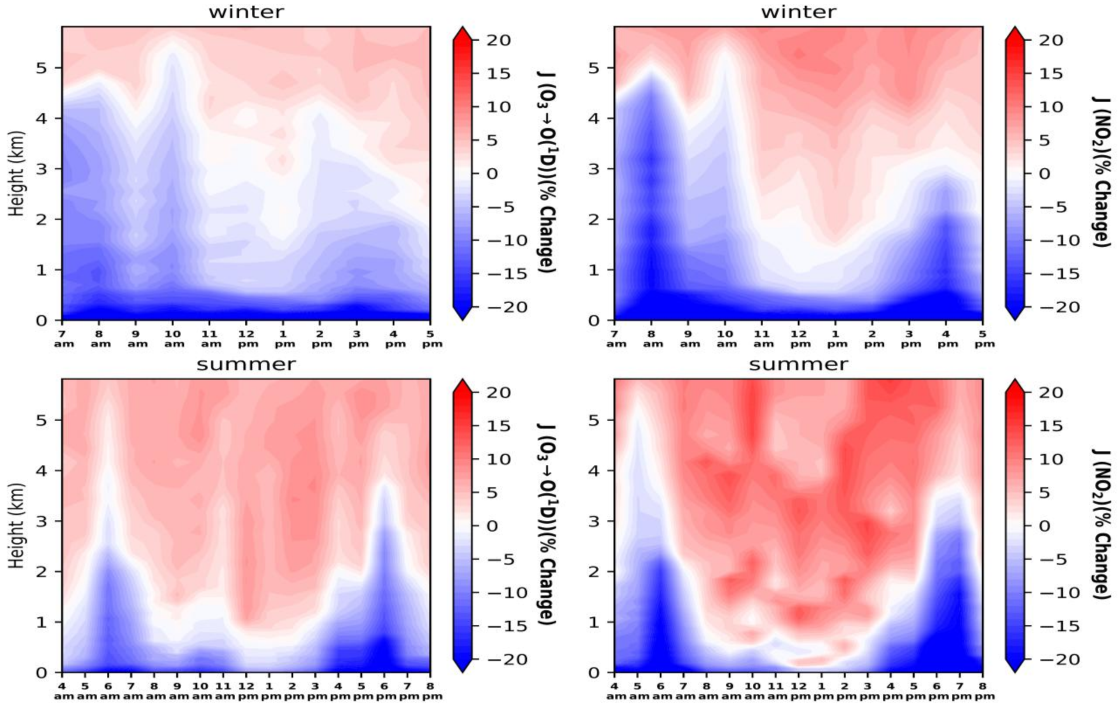
Which aerosols have the largest impact on photolysis rates?

- Absorbers dominate towards the surface, scatterers higher up.
- Effect from absorbers more pronounced through column in winter.
- Absolute changes in J rates higher in the summer.



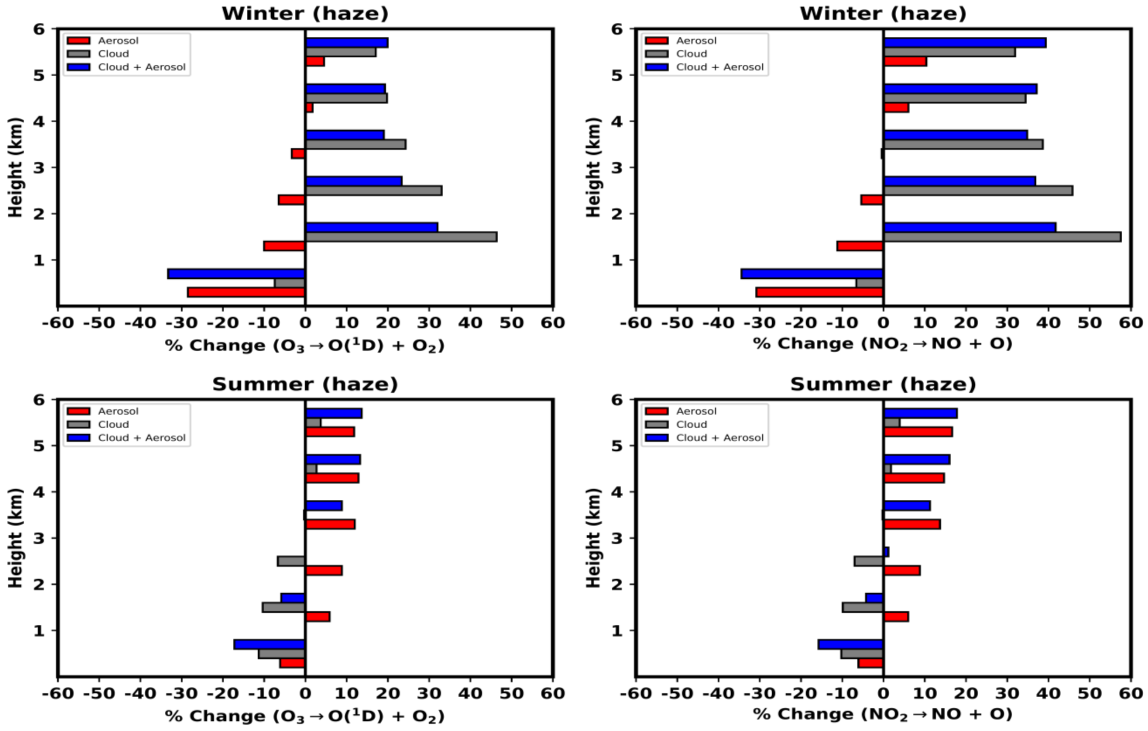
Impacts on mean diurnal JO_3 and NO_2 profiles

- Impacts of all aerosols versus clear sky conditions
- Largest reductions in JO_3 of 33.7% in winter
- Largest reductions in JNO_2 of 66% in summer



Haze impacts versus cloud impacts

- In winter aerosol impacts dominate <1km.
- Aerosol and cloud have similar effects at surface in summer.
- In summer aerosols effects dominate >3km
- Absolute changes in J rates higher in summer!

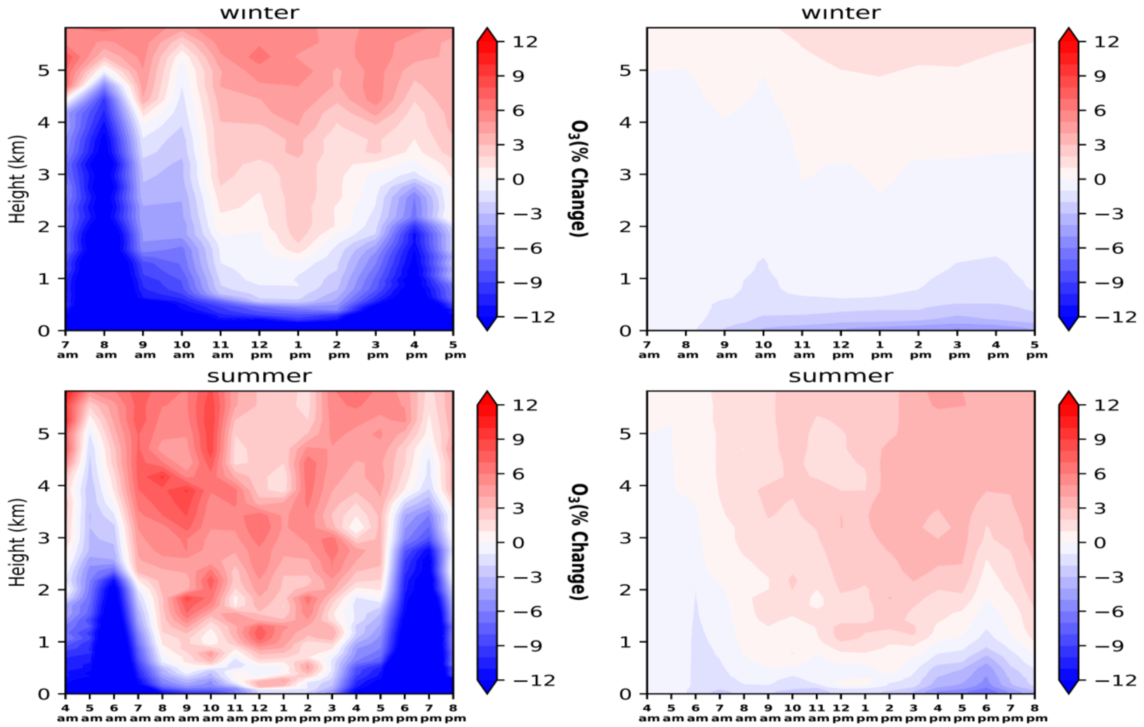


Potential photochemical impacts using a simple box model

- Simple VOC oxidation scheme based around generic reaction set

- Aerosols result in potential reductions of ~12% in surface O_3 concentrations (0.0 to 3.0% for OH)

- What are the implications for oxidants if PM controls implemented?



Summary

- Severe haze pollution episodes occur in both winter and summer resulting in up to 34% reduction in JO_3 (winter) and 66% reduction in JNO_2 (Summer)
- Largest magnitude reductions are seen during summer months – despite PM in general being lower
- Absorbing species dominate response of photolysis rates in winter and scatterers dominate in the summer
- During both campaigns in severe haze pollution aerosol effects dominate over clouds (when present)
- Severe haze potentially reduces surface O_3 and OH concentrations by up to ~12% and 3% respectively
- What are potential feedbacks of PM removal on photochemistry?

Thank You!

Questions?