Interpreting GEMS geostationary satellite observations of the diurnal variation of nitrogen dioxide (NO_2) over East Asia

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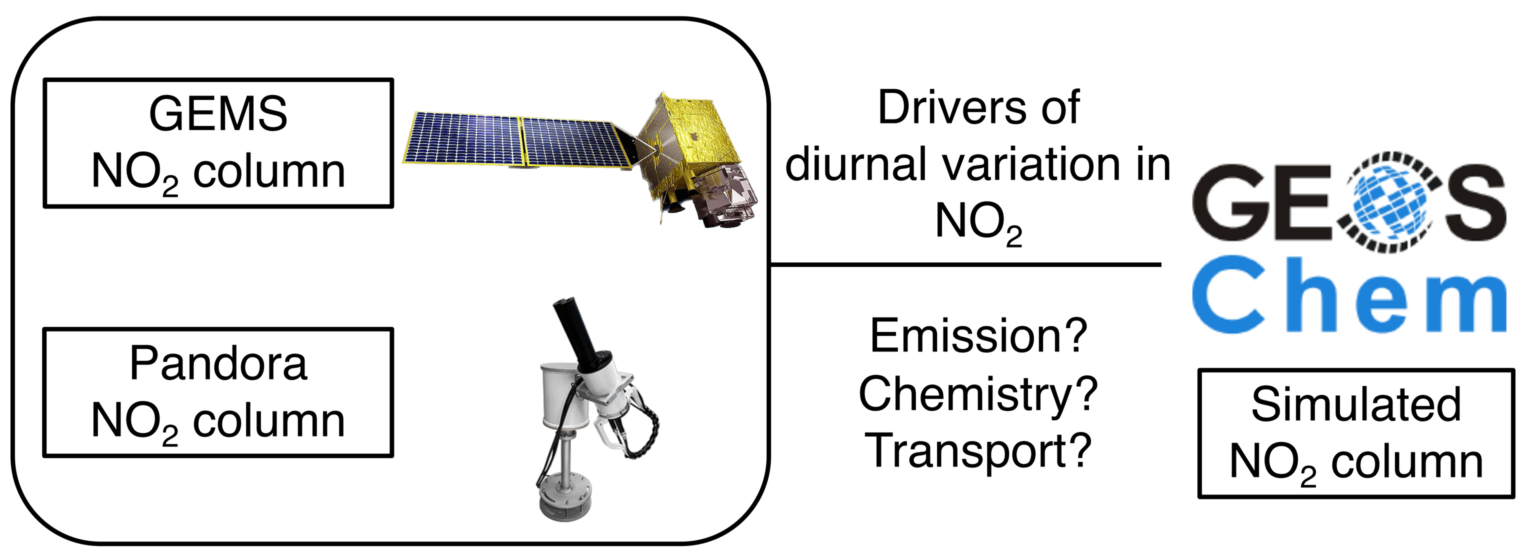
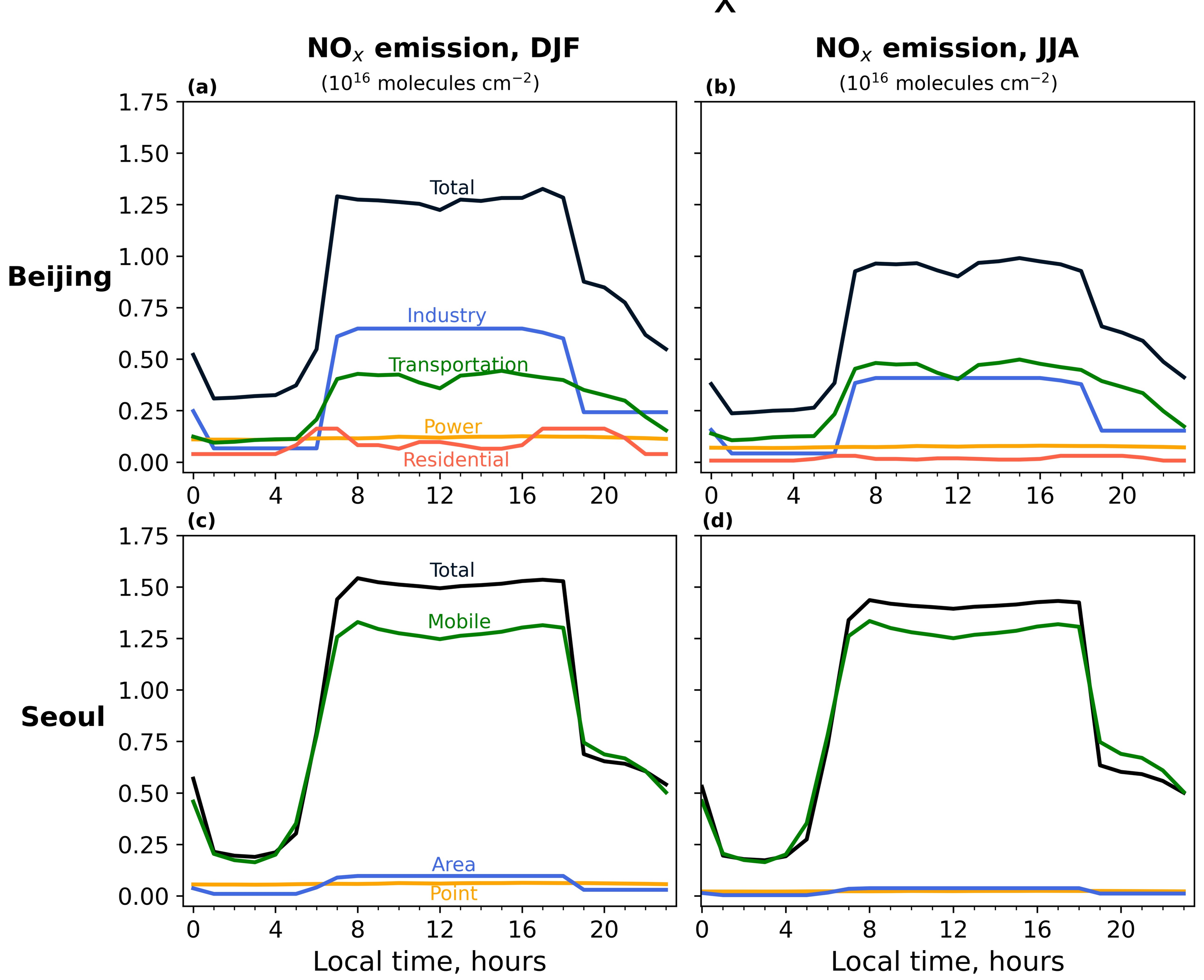
Introduction

- Nitrogen oxide radicals ($NO_x \equiv NO + NO_2$) emitted by fuel combustion are important precursors of ozone and particulate matter pollution.
- The GEMS, launched in space in 2020, now provides hourly daytime observations of NO_2 columns over East Asia.
- Here we investigate the drivers of the diurnal variation of NO_2 observed by GEMS during winter and summer over Beijing and Seoul.

Model & Observations



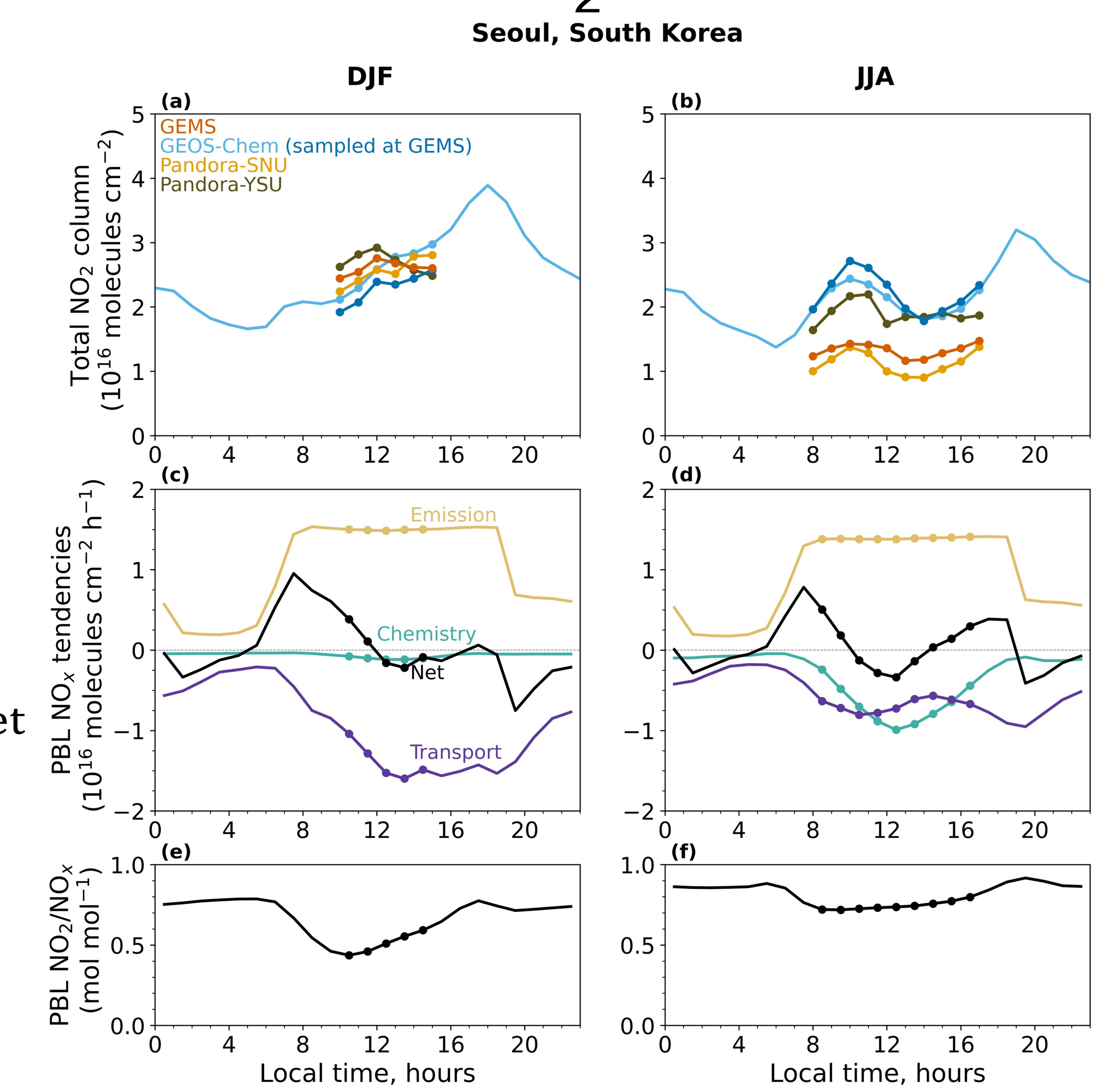
Diurnal variation of NO_x emissions



- Emissions are dominated by industrial and transport sources in Beijing, and by mobile sources in Seoul.
- Both sectors show a broad maximum between 7 and 18 LT.
- There is no significant rush hour peaks in transport emissions, suggesting that surface NO_2 maxima observed in rush hours are driven more by shallow mixing depth.

Diurnal variation of NO_2 over urban core

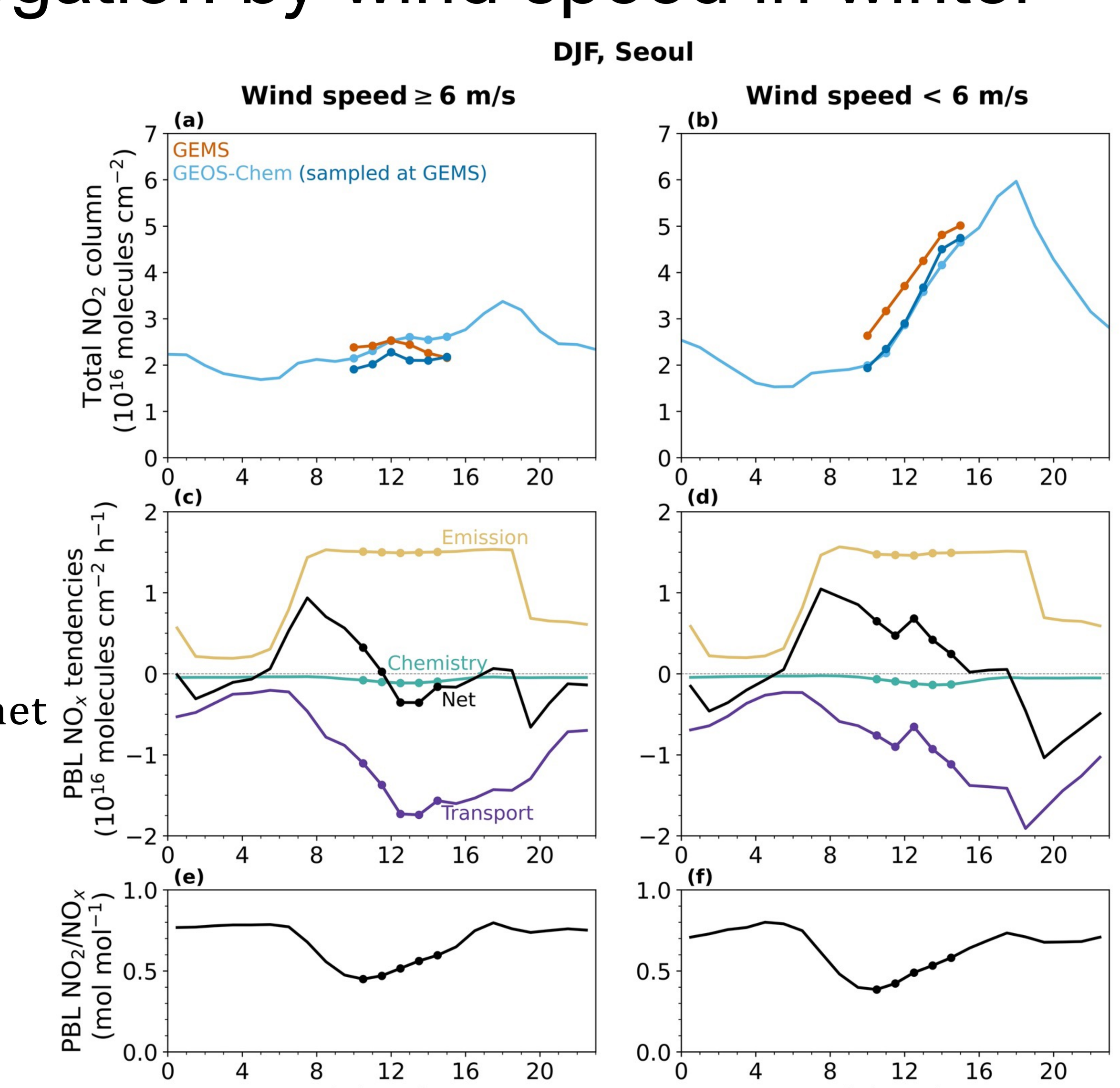
$$\frac{\partial \Omega_{NO_2}}{\partial t} = \left[\frac{\partial \Omega_{NO_x}}{\partial t}\right]_{net} \times \frac{NO_2}{NO_x}$$



- NO_2 in winter increases throughout the day due to high daytime emissions and increasing NO_2/NO_x ratio from entrainment of ozone, partly balanced by loss from transport.
- NO_2 in summer, chemical lass combined with transport drives a minimum in the NO_2 column at 13-14 local time.

Segregation by wind speed in winter

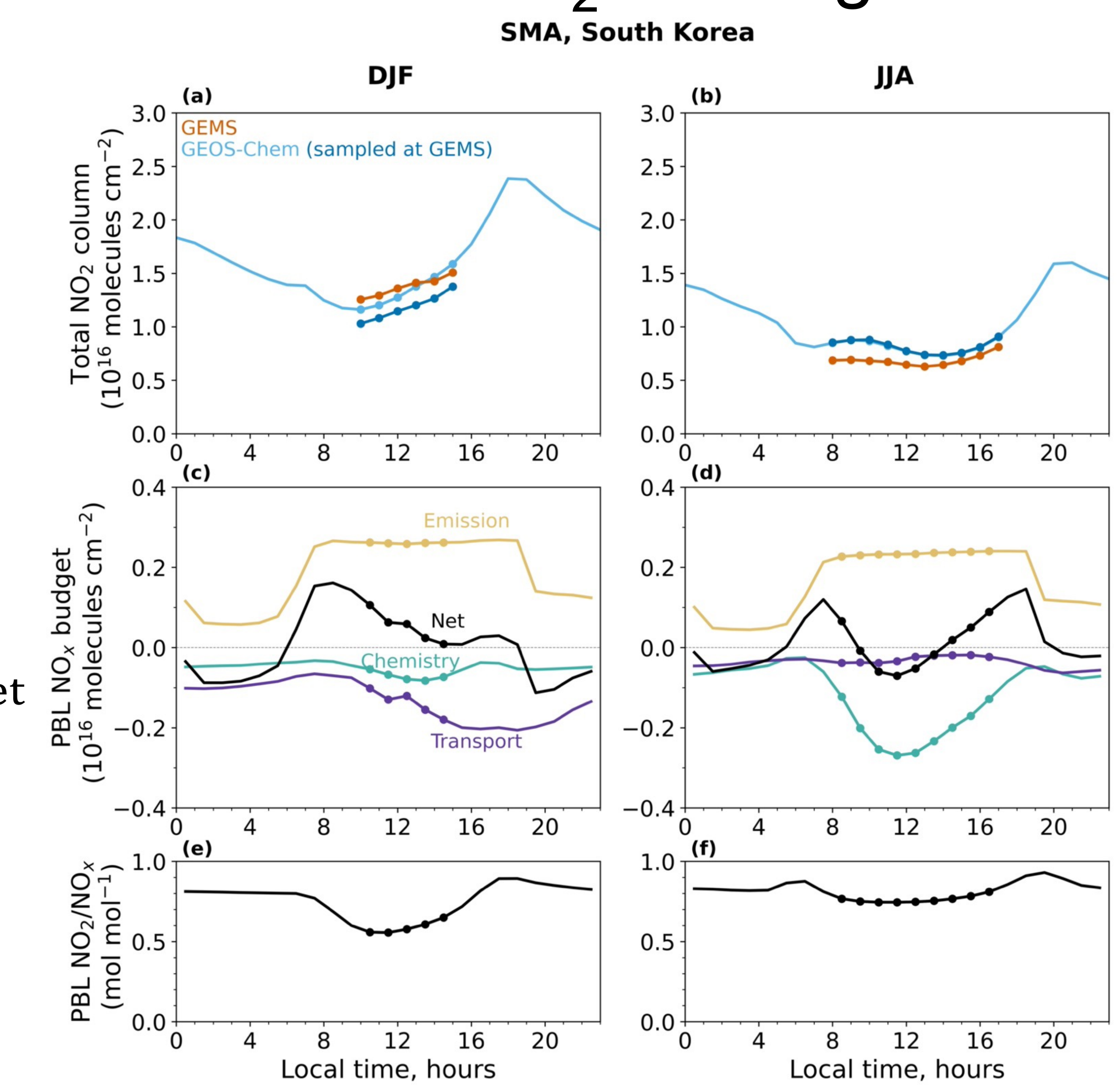
$$\frac{\partial \Omega_{NO_2}}{\partial t} = \left[\frac{\partial \Omega_{NO_x}}{\partial t}\right]_{net} \times \frac{NO_2}{NO_x}$$



- At high wind speed, emission is balanced by transport leading to weak diurnal variation.
- At low wind speed, NO_2 accumulates as transport cannot keep up with emission.

Diurnal variation of NO_2 at a regional scale

$$\frac{\partial \Omega_{NO_2}}{\partial t} = \left[\frac{\partial \Omega_{NO_x}}{\partial t}\right]_{net} \times \frac{NO_2}{NO_x}$$



- In winter, NO_2 shows a steady increase over the daytime hours due to emissions, but the transport term remains the major sink of NO_x.
- In summer, NO_2 shows negligible loss from transport in daytime because chemical loss term is much faster, but the diurnal amplitude is weak because of diluted emission and long residence time.

Conclusions

- We can independently infer the emission in the winter and chemistry in the summer by quantifying the transport term using an inversion with a chemical transport model.
- Our conclusions regarding the interpretation of the diurnal variation of NO_2 columns can be extended to other instruments of geostationary air quality constellation like TEMPO and Sentinel-4.

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- Contact LHY at laurayang@g.harvard.edu
- Read the preprint at EGUsphere: https://doi.org/10.5194/egusphere-2023-2979