Investigating the effects of NO_x emission and chemistry on the diurnal variation of NO_2 over East Asia using ground-based and geostationary satellite observations

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Differences in NO_x ($\equiv$ NO + NO_2) lifetime between different seasons can result in distinct diurnal variations in NO_2 column

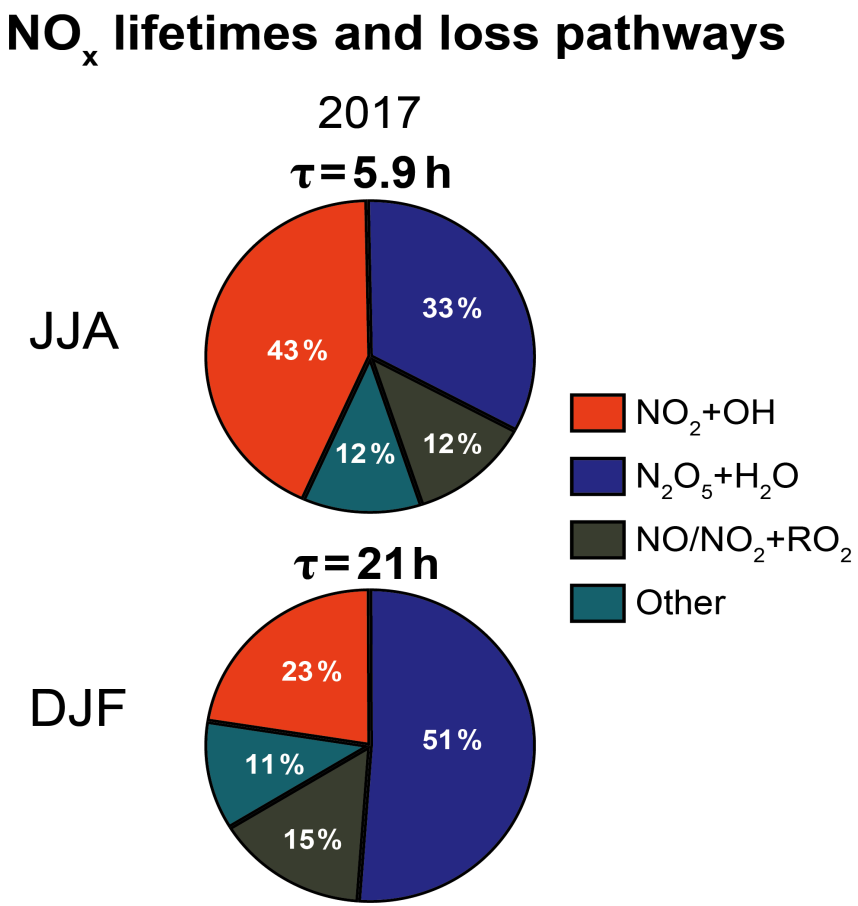


Figure from Shah et al. (2020)

** In the absence of transport **

$$\frac{dN_v}{dt} = \alpha(t)(E(t) - k(t)N_x(t))$$

Trop. NO_2 column

$\frac{NO_2}{NO_x}$ column ratio

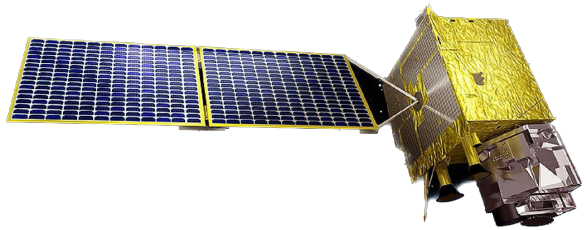
NO_x emission

NO_x chemical loss

Equation from Boersma et al. (2008)

A chemical transport model (CTM) can elucidate the factors driving diurnal variation in retrieved and measured NO_2

GEMS
NO_2 column



Pandora
NO_2 column

Surface
NO_2 concentration

Drivers of
diurnal variation in NO_2

Emission? Chemistry?

GEOS-Chem

Diurnal variation in
simulated NO_2

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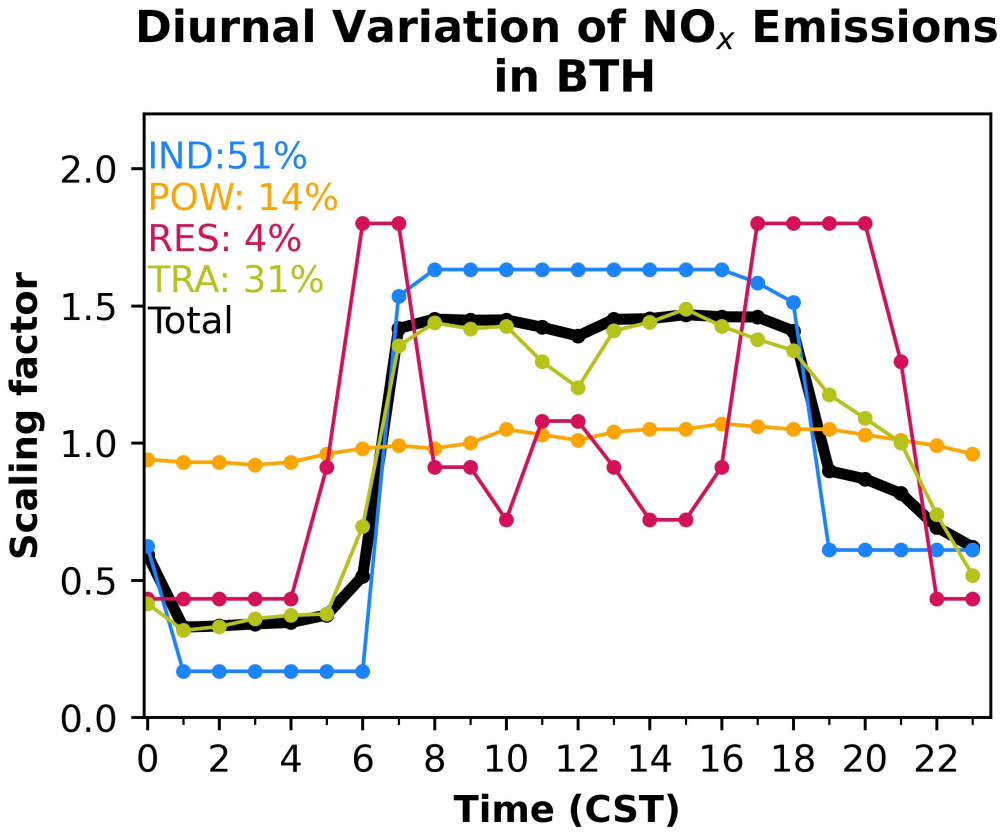
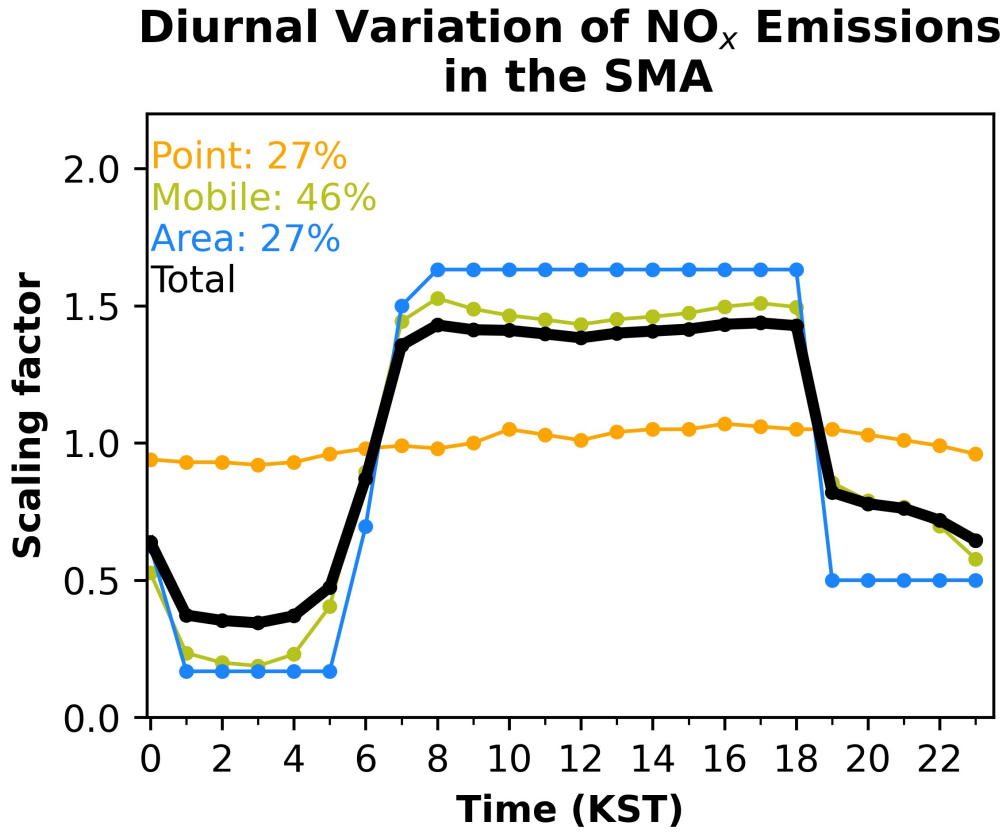
The main difference in diurnal variation of NO_x emissions occurs between day and night, which impacts the morning behavior of NO_2



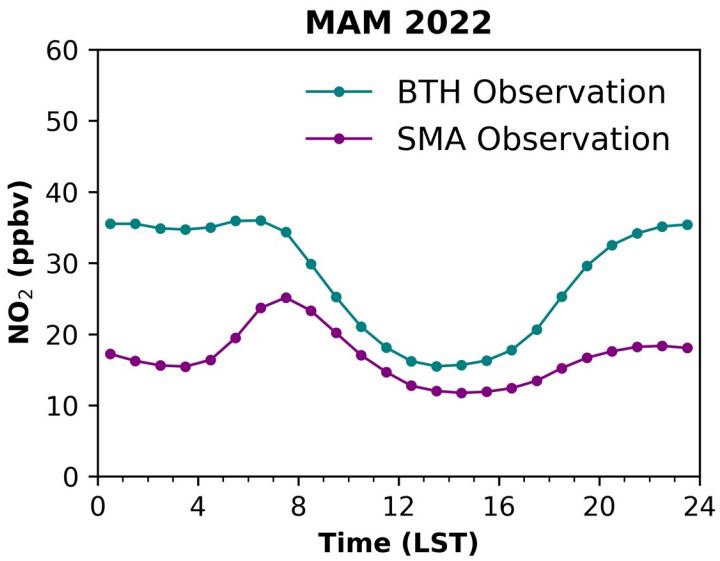
MEIC inventory diurnal scaling factor (Miao et al. 2020)

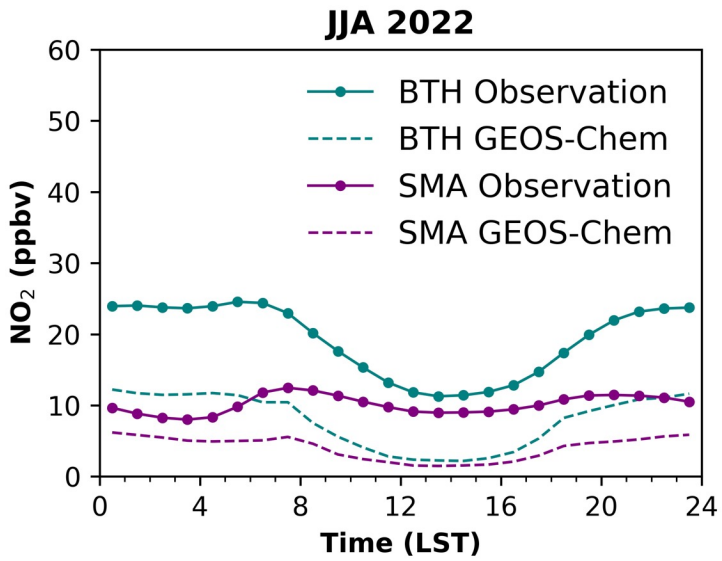


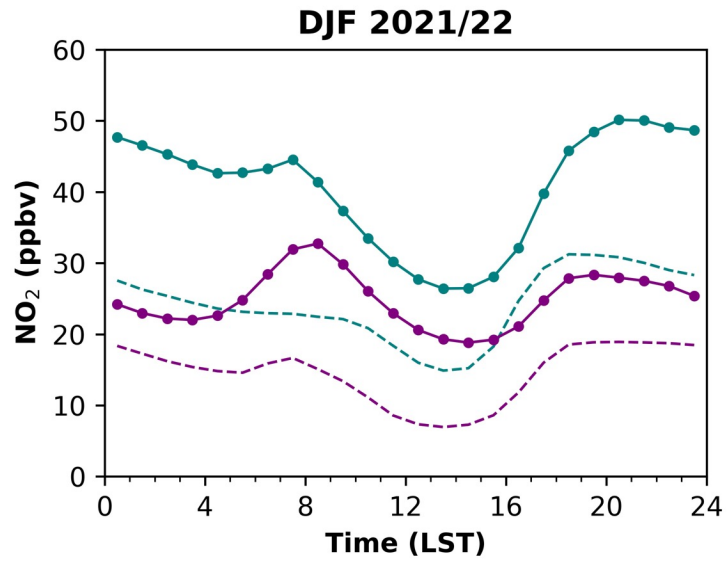
Developed KORUSv5 scaling factor based on TOPIS traffic count and construction activity time

NO_2 diurnal variation from surface measurements in summer (JJA) is affected by monsoon

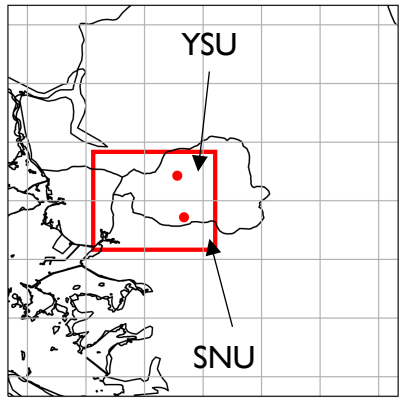
Mixed layer growth complicates interpreting diurnal variation of NO_2 from surface measurements

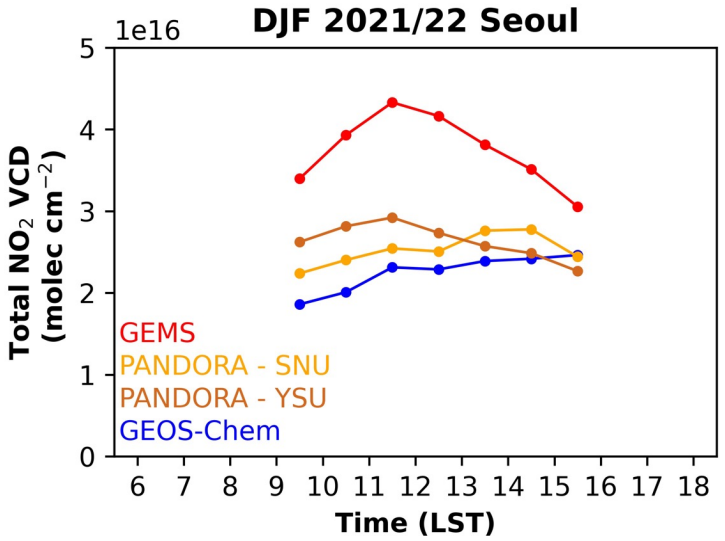


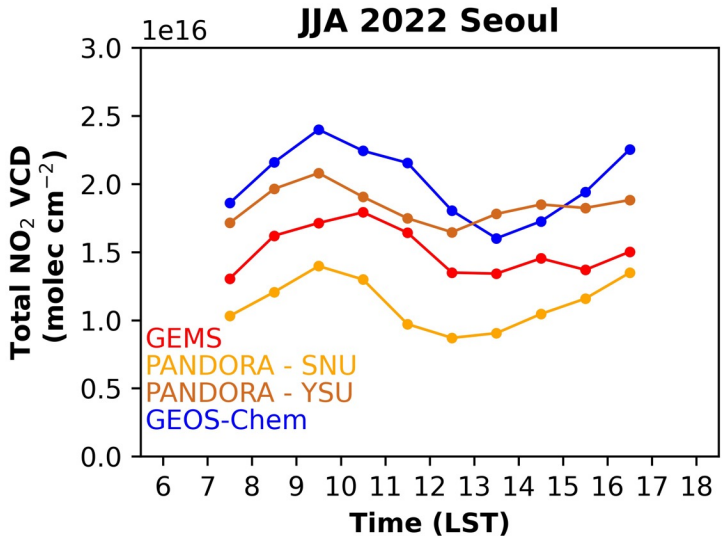


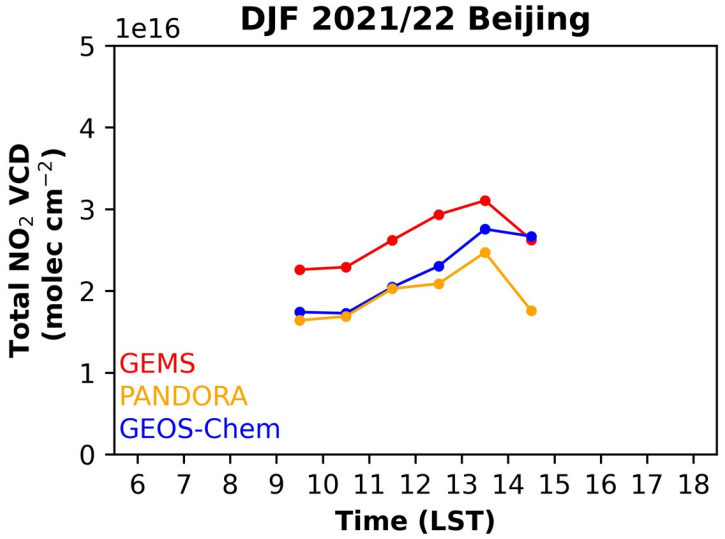


Pandora NO_2 column measurements are sensitive to advection





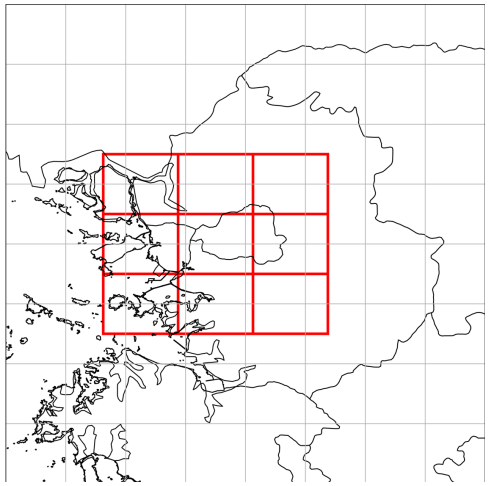




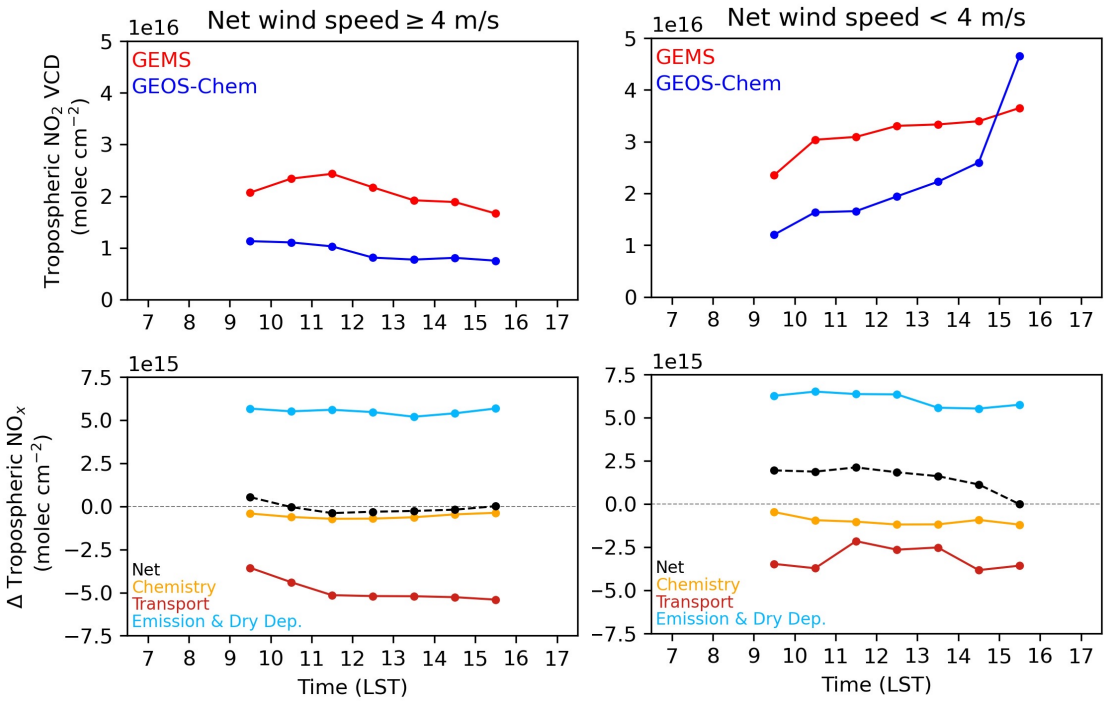
Too few Pandora measurements available for JJA

GEMS and GEOS-Chem from one 0.25° × 0.3125° grid box
Dot shows the location of the Pandora station

Extended NO_x lifetime and stronger wind in the winter increases effect of transport, complicating urban-scale diurnal analysis using GEMS



nine 0.25° × 0.3125° boxes



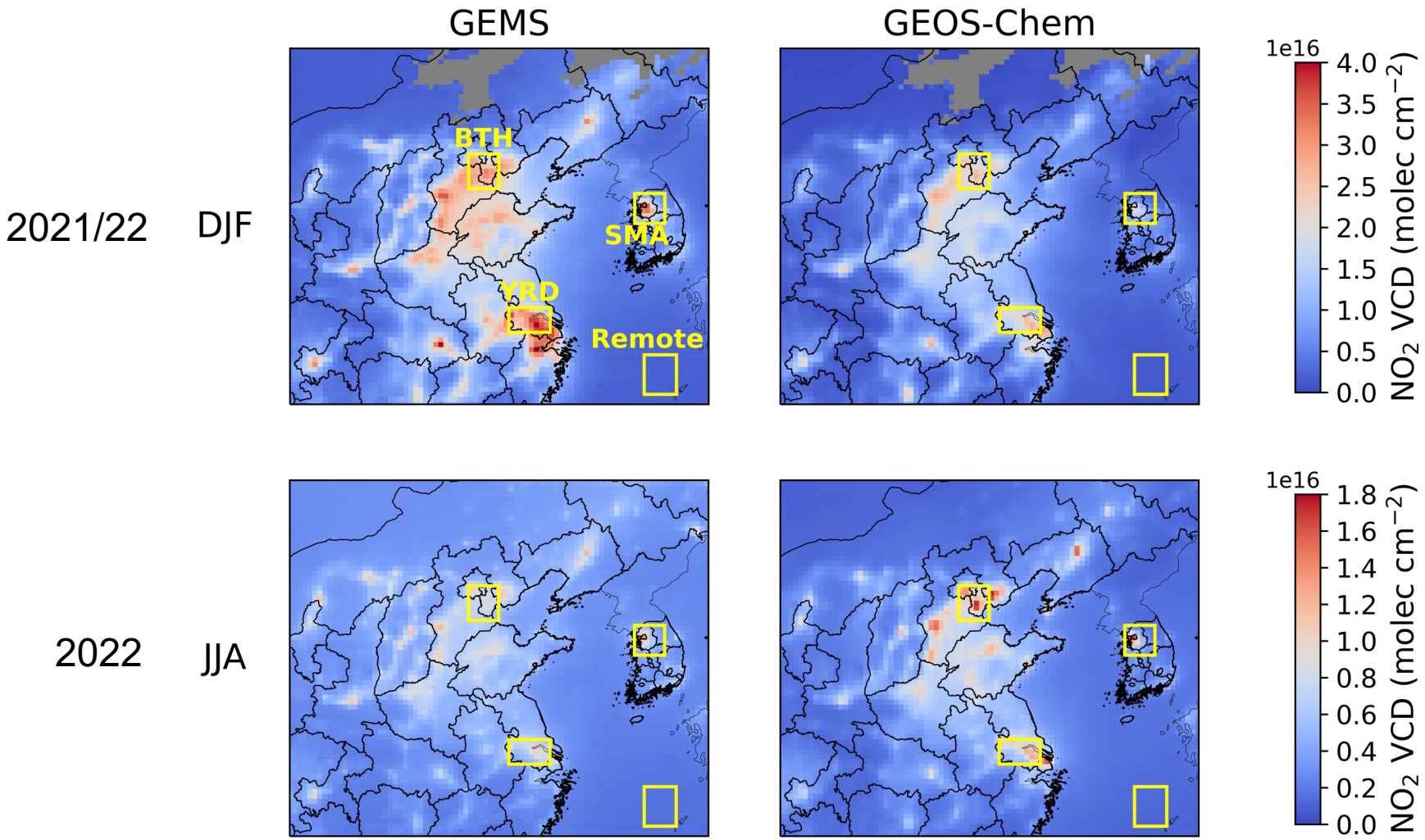
Trop. NO_2 column

$$\frac{dN_v}{dt} = \alpha(t)(E(t) - k(t)N_x(t) - \nabla \cdot N_x(t)U)$$

$\frac{NO_2}{NO_x}$ column ratio; NO_x emission; NO_x chemical loss; Transport

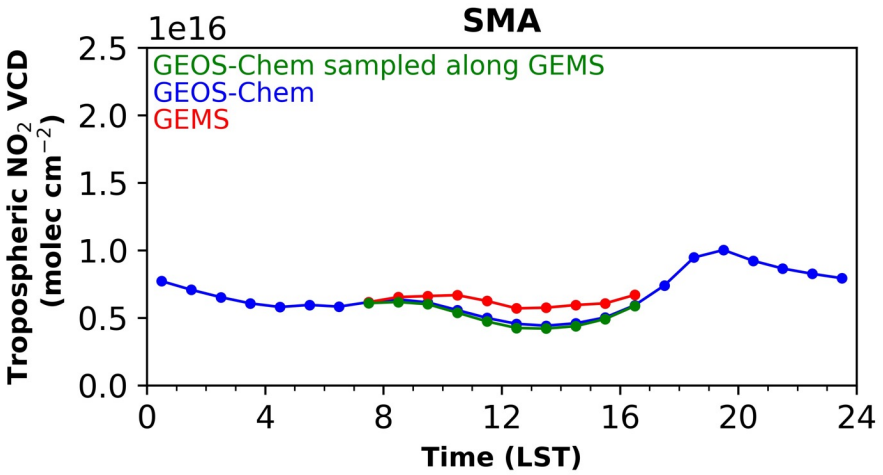
- Strong Northwesterly winds blow over the Seoul Metropolitan Area (SMA) during the winter (Seo et al. 2021)
- Over a small horizontal domain, the transport term becomes important
- Spatial averaging over large domain is needed to minimize the effect of the transport term

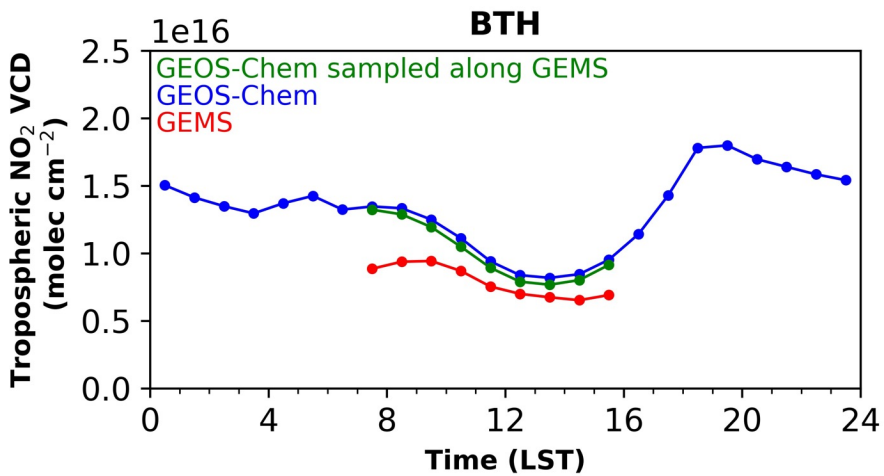
A wider spatial domain is required to reduce the impact of transport when interpreting the diurnal variation of NO_2

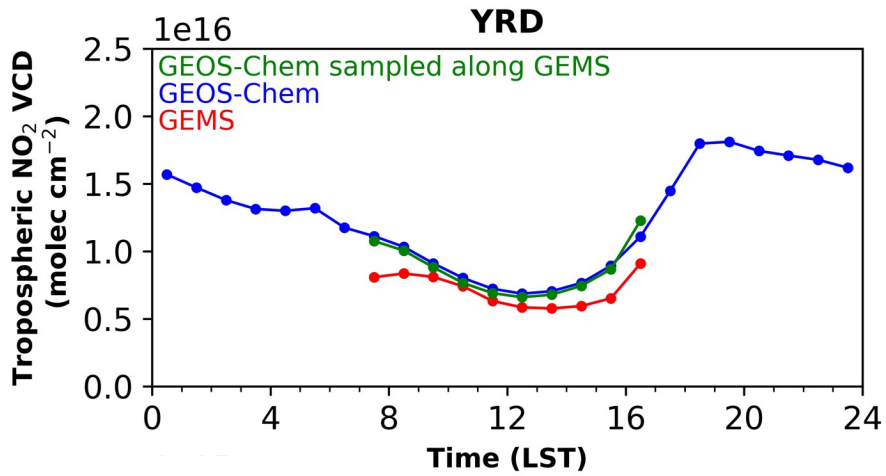


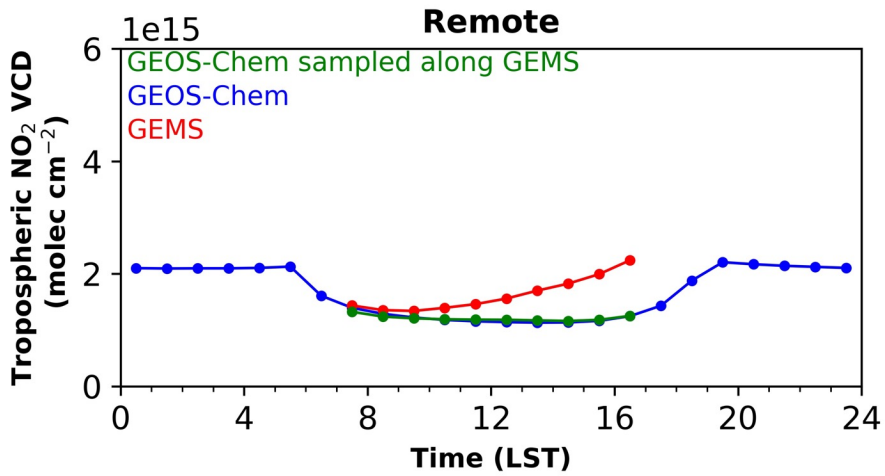
** DJF and JJA have different y-axis scale **

In the summer, emission regions exhibit an accumulation of emissions in the early morning, followed by a decrease driven by chemical processes



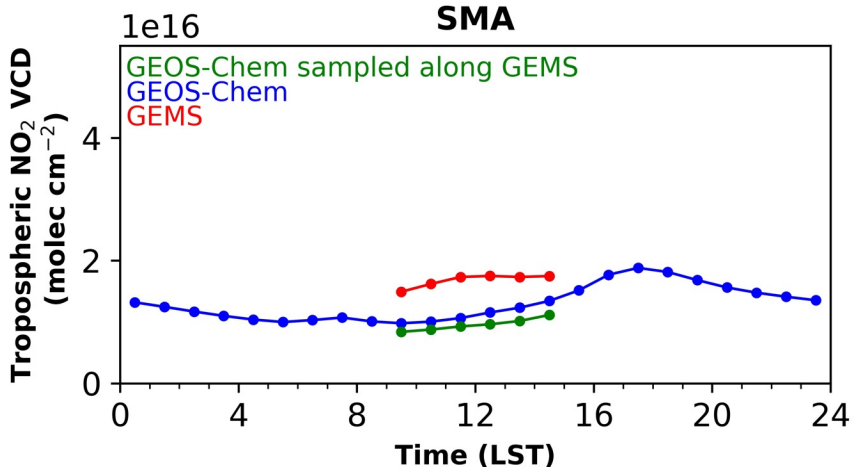


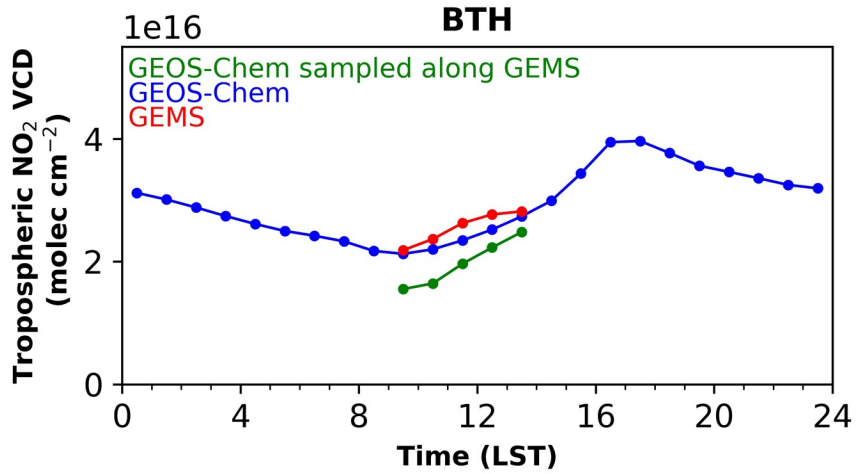


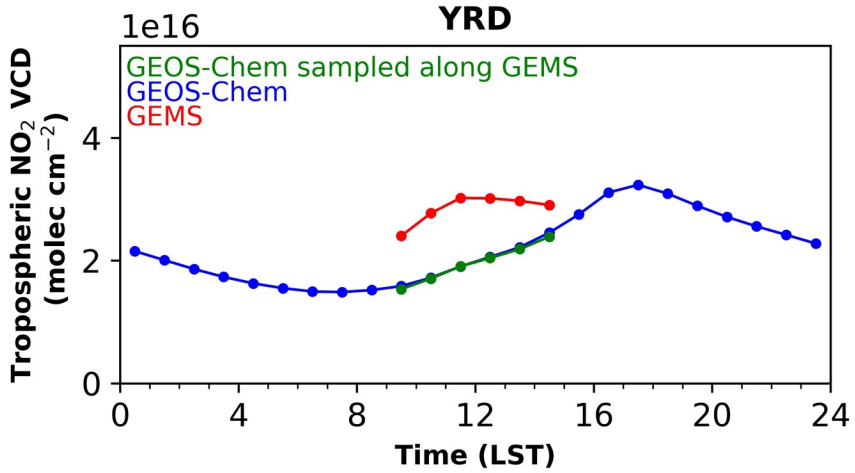


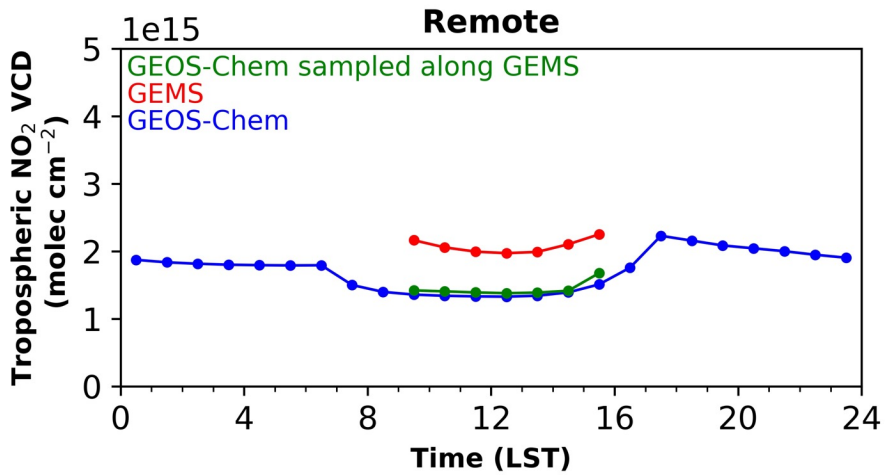
*** BG1 has a different y-axis scale*

In the winter, the accumulation of high emissions lead to a net increase in the NO_2 column over emission regions









*** Remote site has a different y-axis scale*

Takeaways

During summer, the diurnal variation of the NO_2 column is driven by active photochemistry while in winter, it is driven by emission

Urban-scale analysis can be complicated by the transport term and must be done carefully especially during the winter over East Asia

GEOS-Chem agrees with GEMS observations and can provide an explanation for the observed diurnal variation in GEMS