Assessing surface ozone-NOx-VOC sensitivity in major Indian cities using high resolution TROPOMI observations

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November 16, 2022

Abstract

Policies to regulate severe surface ozone pollution in cities in India are challenging to develop, due to the complex dependence on precursor emissions of volatile organic compounds (VOCs) and nitrogen oxides (NOx), non-linear chemistry leading to ozone formation, and very limited spatial and temporal surface air quality monitoring. Ratios of space-based observations of formaldehyde (HCHO), an intermediate oxidation product of VOCs, and nitrogen dioxide (NO2) have been used to characterize the sensitivity of surface ozone production to precursor emissions of VOCs and NOx, but interpretation of these depends on the local oxidation regime. Here we develop an improved approach in which we discretize the data into background HCHO due to methane and other long-lived VOCs (regression intercept) and the local relationship (regression slope) between HCHO associated with reactive VOCs and NO2. We apply this to TROPOMI HCHO and NO2 tropospheric columns oversampled to higher spatial resolution than the native pixel resolution of the instrument over the ten most populous cities in India. We use GEOS-Chem to characterize the ozone production regimes and then apply this updated interpretation of the relationship between HCHO and NO2 to the oversampled TROPOMI columns to identify the most effective strategies for regulating ozone and whether these should vary seasonally and spatially.

Assessing surface ozone sensitivity in major Indian cities to NO_X and VOCs using TROPOMI

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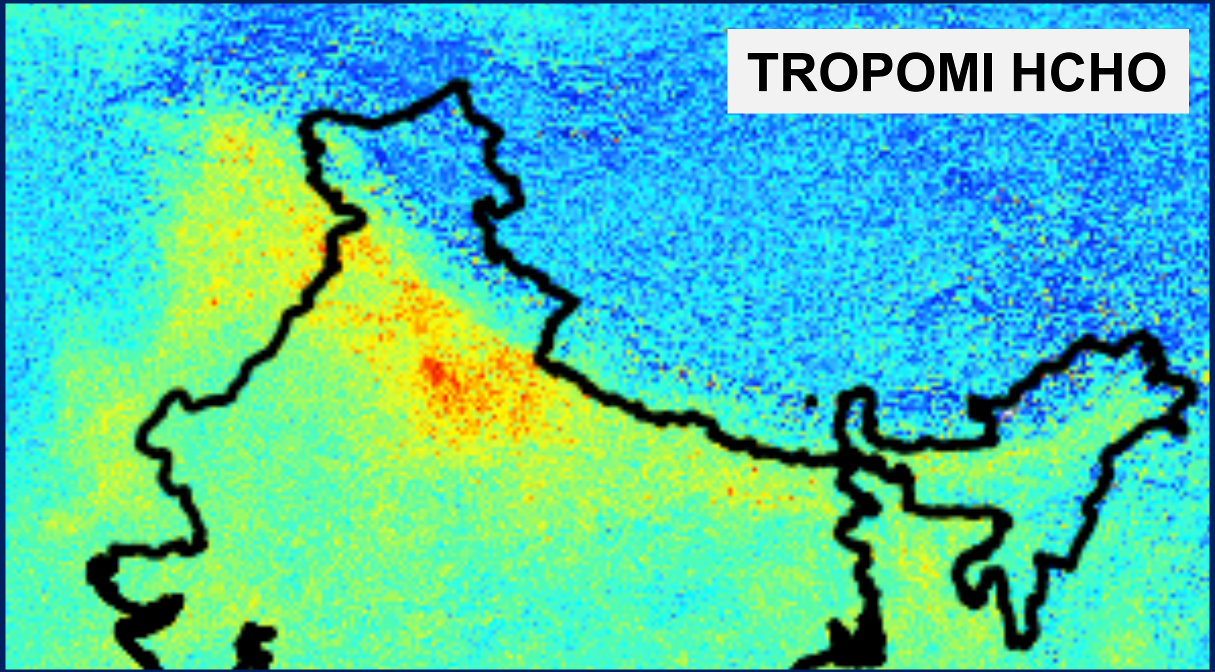

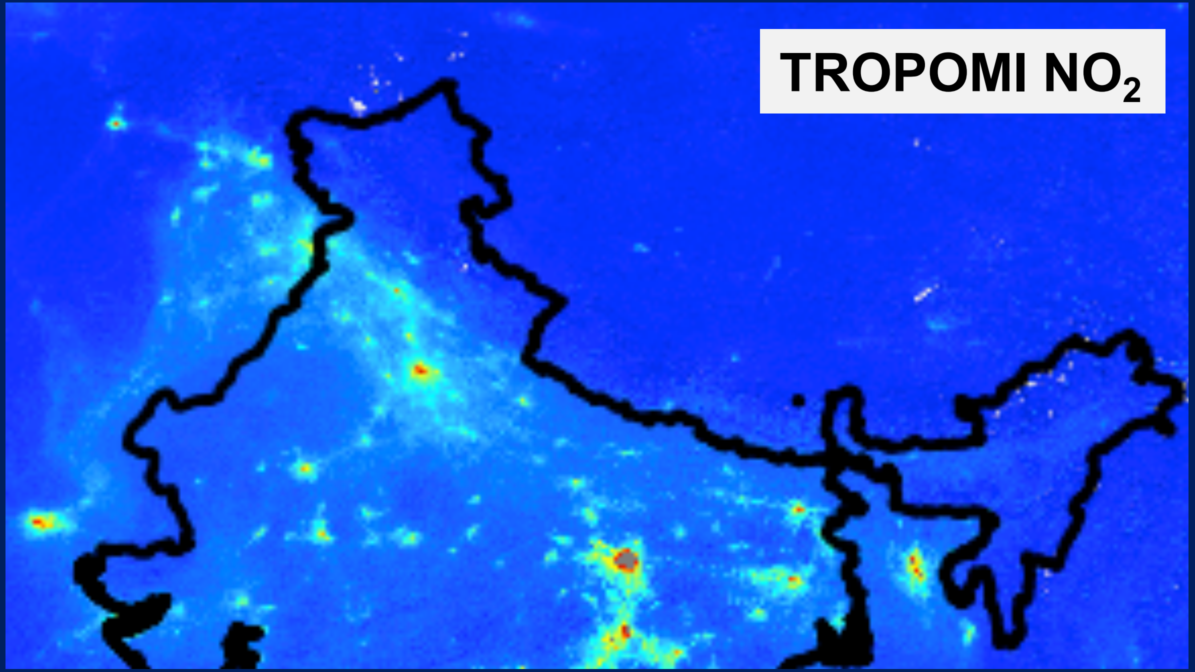

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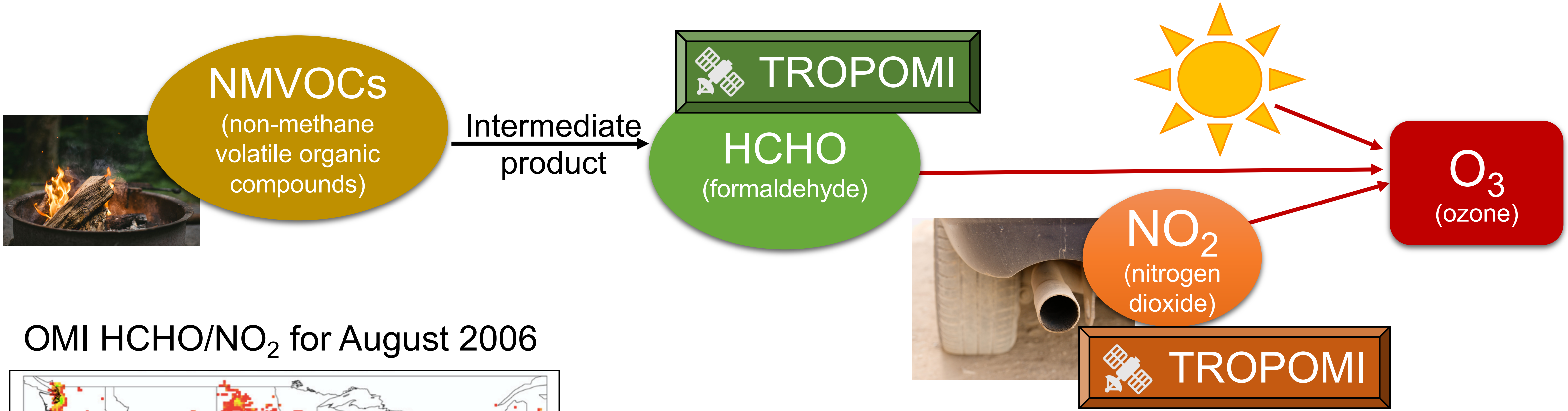
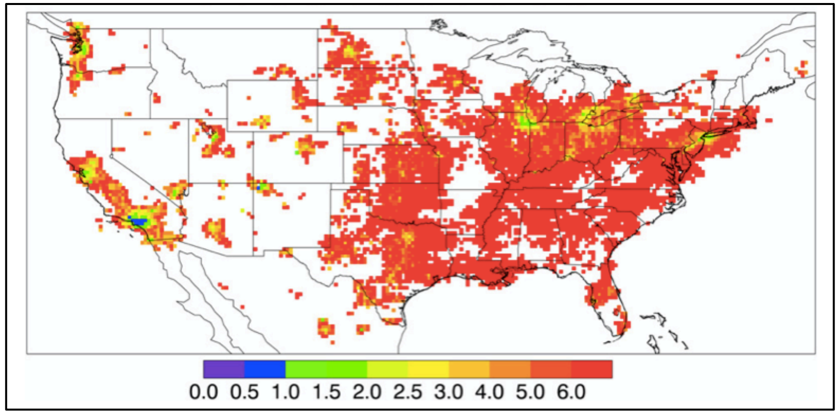
$HCHO/NO_2$ as indicator of O_3 production sensitivity



OMI $HCHO/NO_2$ for August 2006



[Duncan et al., 2010]

$HCHO/NO_2$

$< 1 \Rightarrow NO_X$-saturated
$> 1 \Rightarrow NO_X$-sensitive

[Martin et al., 2004]

Limitation

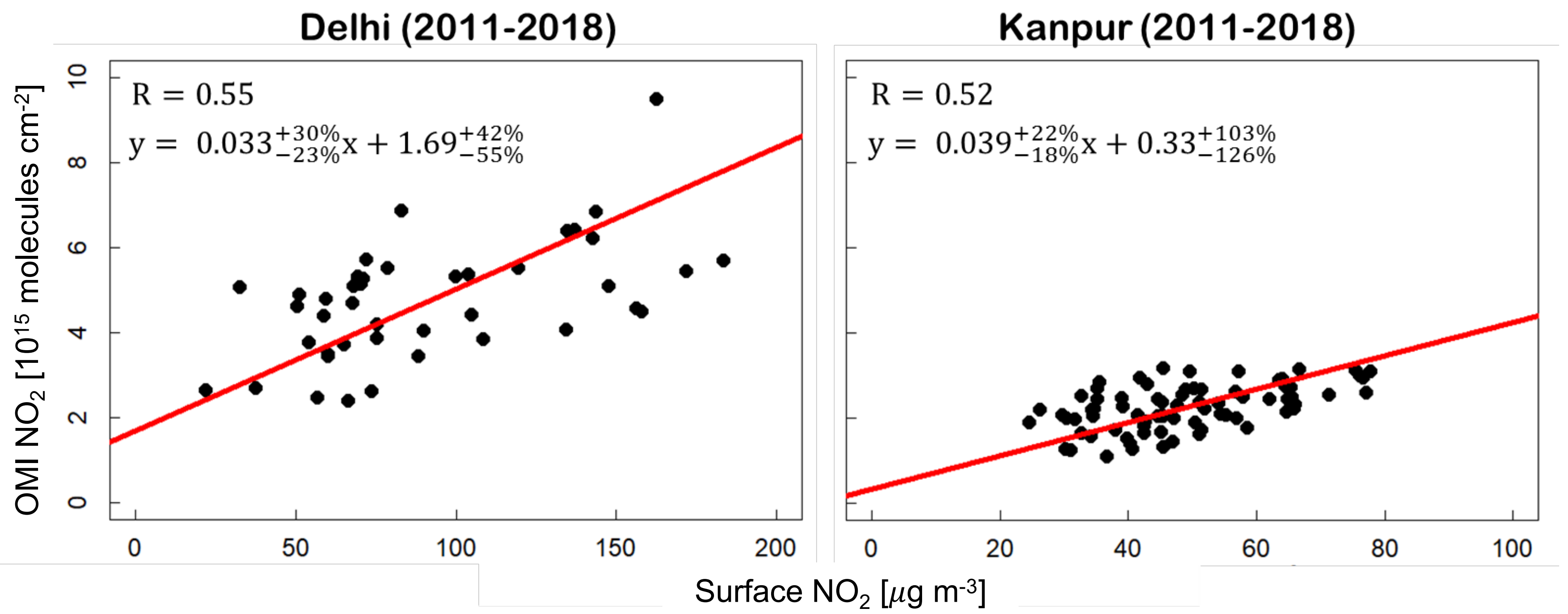
Depends on local oxidation regime and thus the transition across regimes varies with space & time

[Jin et al., 2017; Souri et al., 2020]

In this study, we use TROPOMI observations to assess surface O_3 sensitivity to NO_X and VOCs

Assessment of Earth observations

Satellite vs surface NO_2 in Indian cities



Points are monthly average

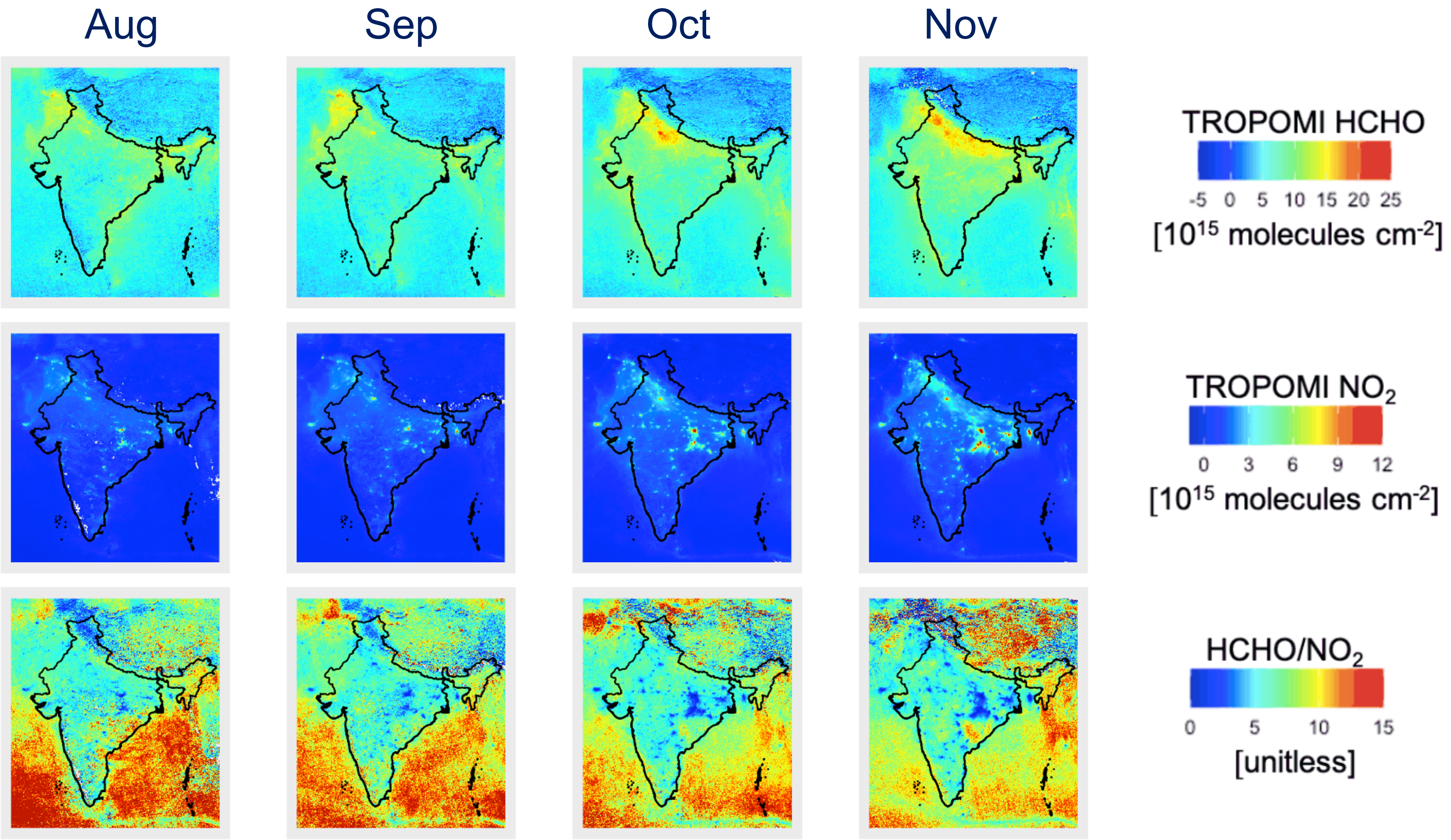
Earth observations can reproduce variability in surface air pollution

[Vohra et al., in review, *ACPD*]

Assessing ozone production regime over India

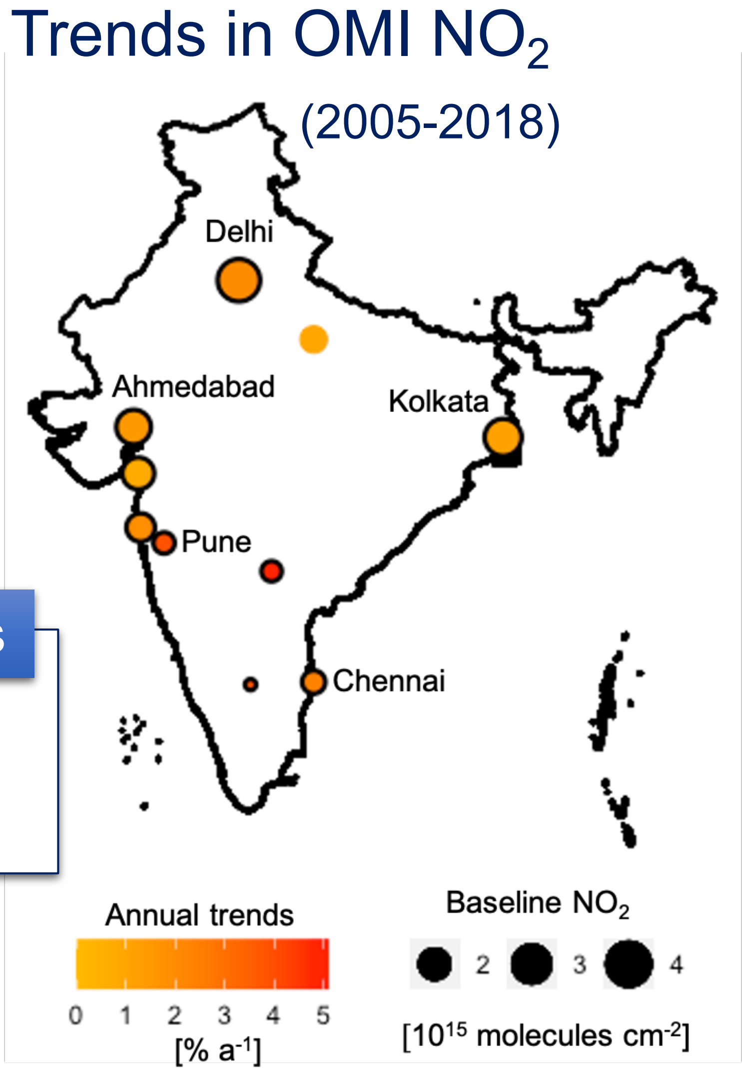
TROPOMI observations for Aug-Nov 2019 $(0.1° \times 0.1°)$

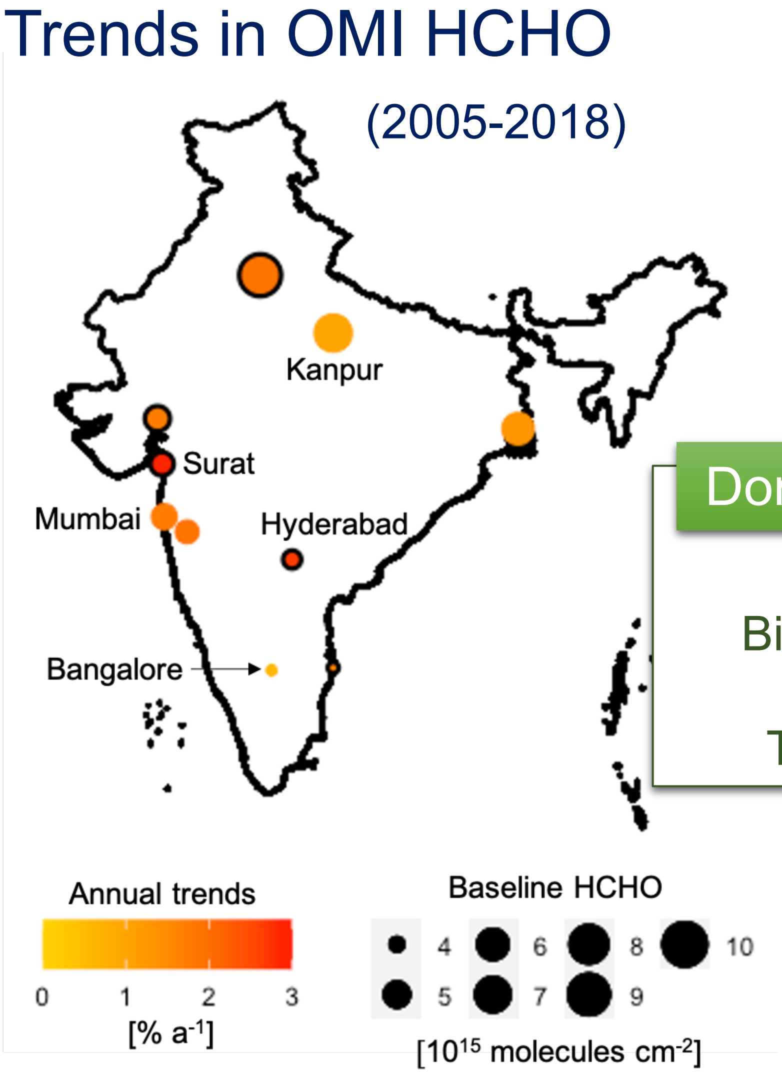
Monsoon (Aug/Sep)
Biomass burning (Oct/Nov)



Most of India is in NO_X-sensitive regime except for Delhi and coal-mining regions

Long-term trends in O_3 precursor sources of NO_X and VOCs





Significant trends are outlined

Dominant sources (NO2)

Industrial
Transportation
Biomass burning

Dominant sources (HCHO)

Biogenic
Biomass burning
Combustion
Transportation

Increase in NO_2 is larger and more significant compared to HCHO increase; suggesting increase in O_3 production in NO_X-sensitive areas

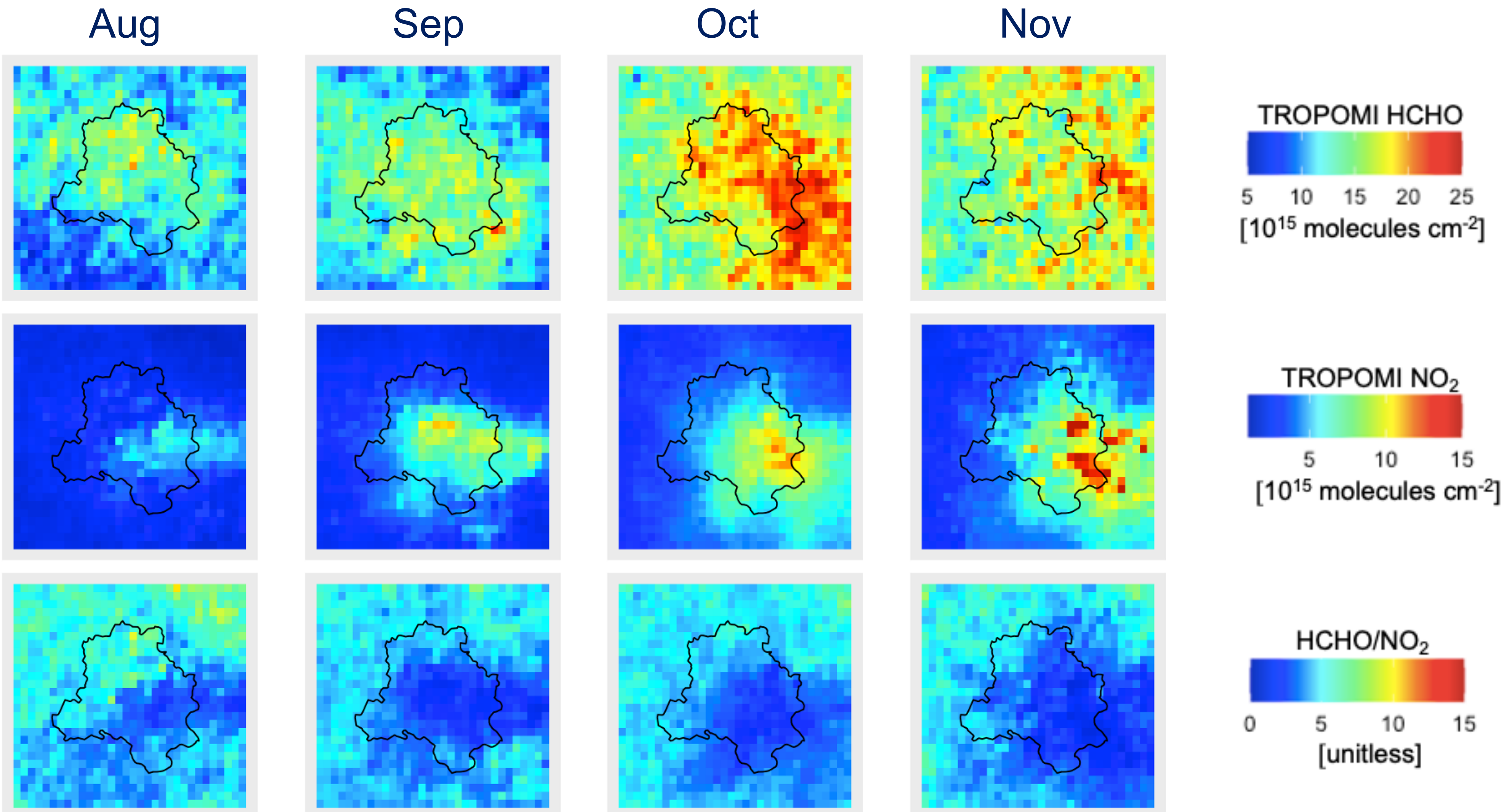
Assessing ozone production regime in Delhi

Oversampled TROPOMI observations for Aug-Nov 2019

$(0.025° \times 0.025°)$

Monsoon (Aug/Sep)

Biomass burning (Oct/Nov)



High HCHO across Delhi during biomass burning but NO_2 elevated only in eastern Delhi leading to two distinct ozone production regimes

Conclusions and next steps

- ✓ We have an initial look at the influence of VOCs and NO_X on ozone production in India and Delhi
- ✓ TROPOMI observations over India are used to derive $HCHO/NO_2$ at regional (~10 km) and local (2.5 km) resolutions
- ✓ Preliminary results show most of India in NO_X-sensitive regime and Delhi in NO_X-saturated regime during August-November 2019
- ✓ Long-term increasing NO_2 trends suggest increase in O_3 formation for most of India (no evidence of improvements due to recent air quality policies)
- ❑ We intend to develop an updated approach aided by interpretation with a chemical transport model to identify the most effective strategies for regulating ozone

Any questions? kxv745@bham.ac.uk @kohra_thefog