Estimating landfill methane emissions in Indian megacities with Sentinel 5p TROPOMI

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Image Credit: Associated Press

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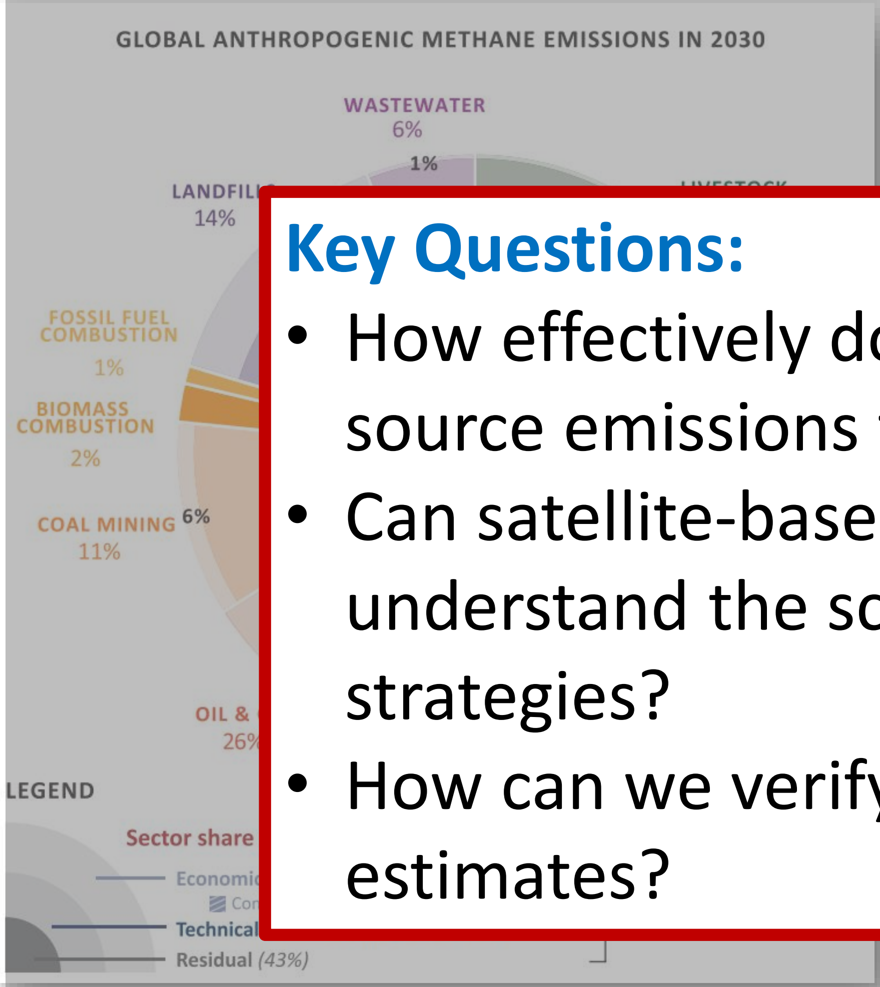
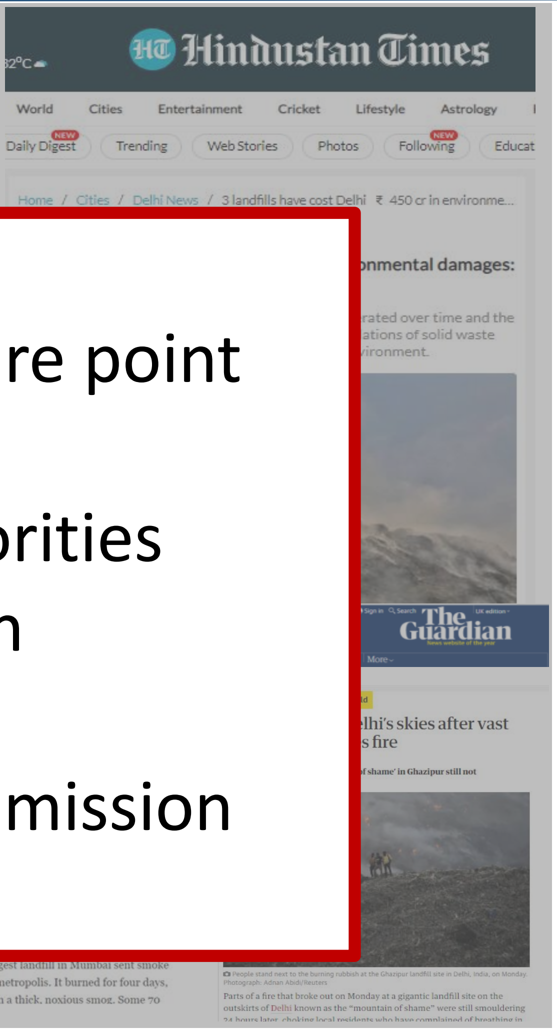
Motivation



- Landfill gas (LFG) natural by-product of the decomposition of organic material in landfills

combating climate change



Key Questions:

- How effectively does the S5p TROPOMI sensor capture point source emissions from landfills?
- Can satellite-based monitoring help regulatory authorities understand the scale of problem to enable mitigation strategies?
- How can we verify satellite-based point source CH_4 emission estimates?

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Point Source Detection

- Satellite sensors -> potential to map CH_4 emissions from point sources

GHGSat-D Satellite Observation
February 15th, 2020

CH_4

Essential requirements to detect and quantify point source emission estimates:

- Local meteorological conditions for the consideration of the vertical and horizontal dispersion of the plume
- A realistic representation of the background CH_4 concentrations to infer enhancements
- Accurate isolation of “plume” pixels to define the full extent of the enhanced features

- Integrated mass enhancement [Varon et al. 2018, 2019, Cusworth et al. 2021]

1880 1920 1960 2000 2040 2080
Methane (ppb)

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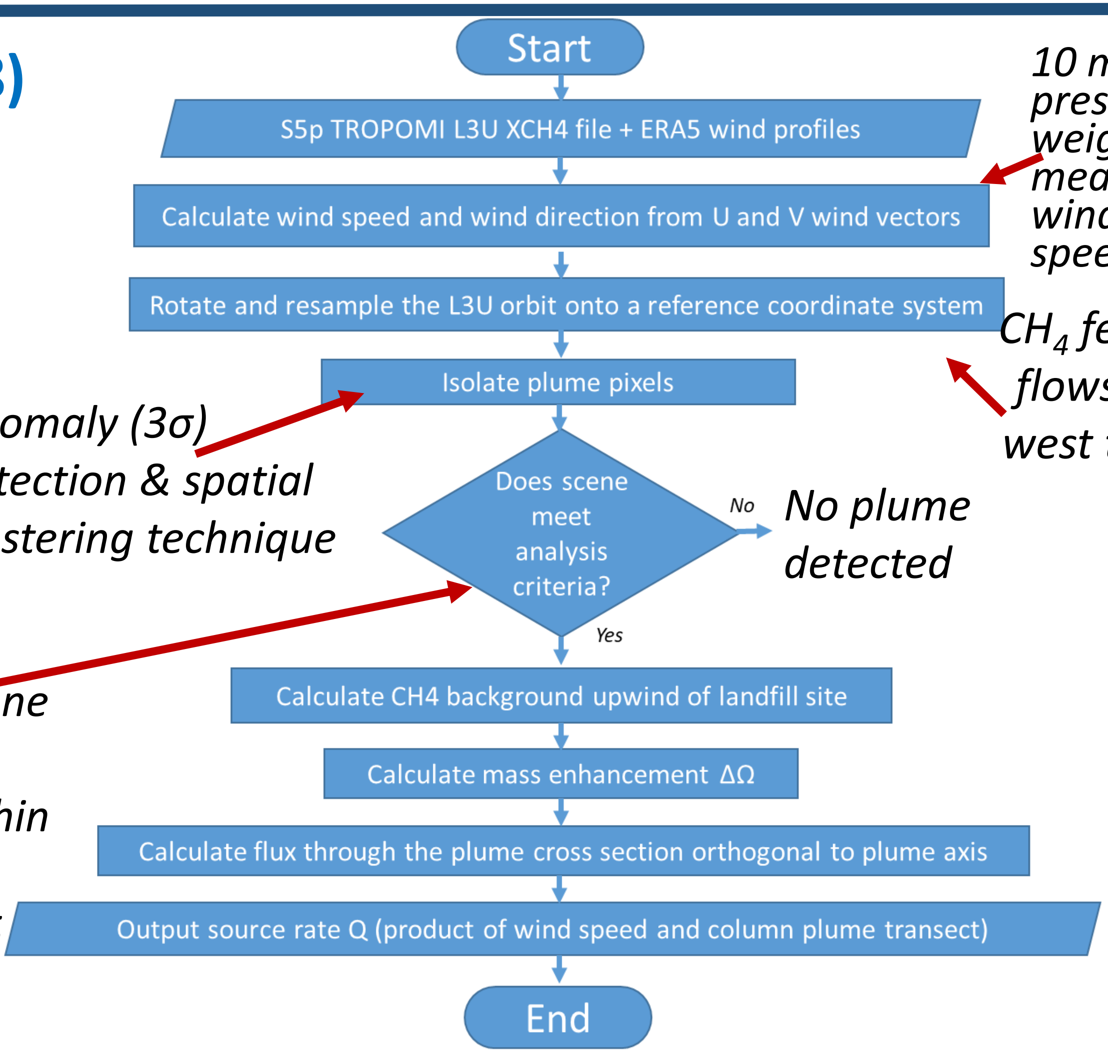
Methodology

Cross-sectional flux method (Varon et al. 2018)

$$Q = \int_{-\infty}^{+\infty} U(x,y)\Delta\Omega(x,y)dy$$

- Source Rate [kg/s] (Q)
- Wind speed [m/s] (U)
- Along plume (x)
- CH4 mass enhancement [kg/m²] ($\Delta\Omega$)
- Across plume (y)



10 metre or pressure weighted mean PBL wind speeds

CH_4 features flows from west to east

Anomaly (3σ) detection & spatial clustering technique

No plume detected

Conditions to be met:
> 75% valid pixels in scene (4˚x 4˚ box around site)
> 2 m/s wind speed within plume area
CH_4 enhancements < 15 km to east of the site

Wind speed estimation (up to 65 % error in Q) is largest source of error

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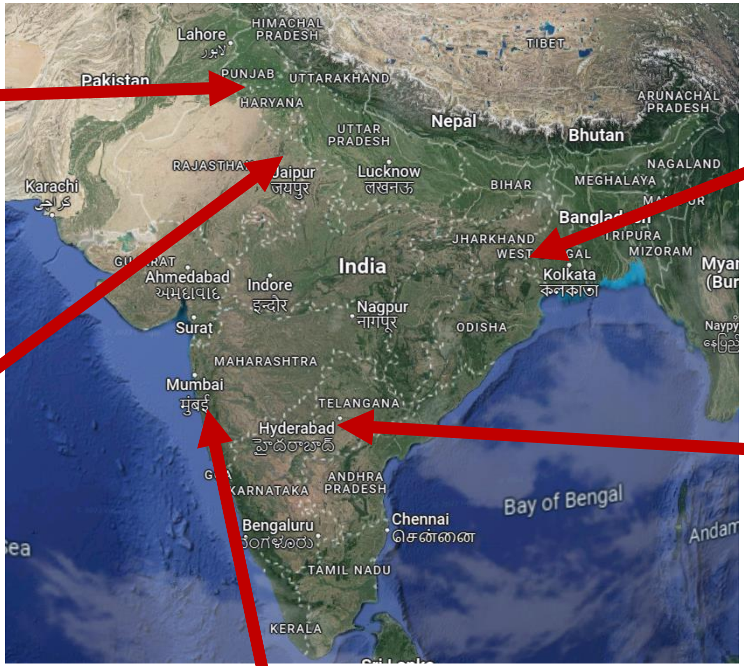
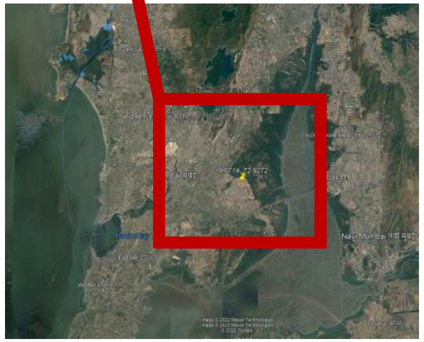
Landfills in Indian Megacities

Tajpur Road
Ludhiana
(pop. 1.8 Mil)
~40 acres
~ 1000 t/day

Ghazipur
Delhi
(pop. 20 Mil)
~ 80 acres
~ 3000 t/day





Deonar
Mumbai
(pop. 21 Mil)
~326 acres
~6000 t/day

Dhapa
Kolkata
(pop. 14 Mil)
~61 acres
~2500 t/day

Jawahanagar
Hyderabad
(pop. 10 Mil)
~300 acres
~6000 t/day

Urban/built up megacities
Intensive agricultural region
Wetland regions
Sparsely vegetation regions

Image credit: Google Earth

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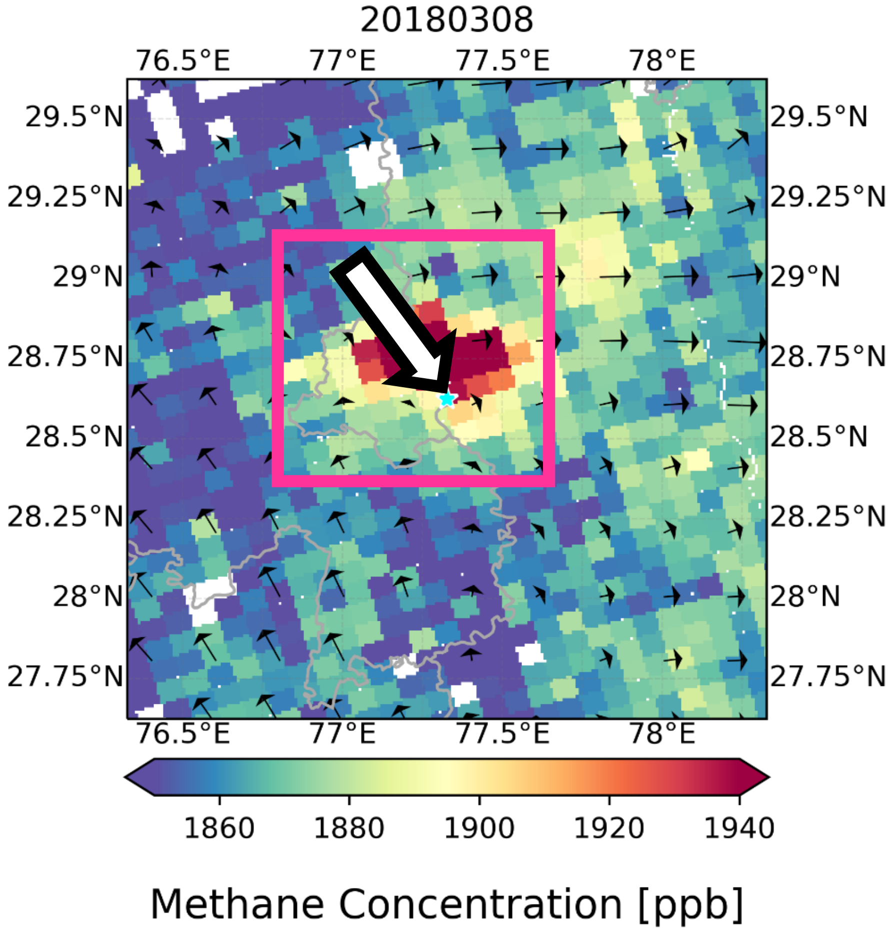
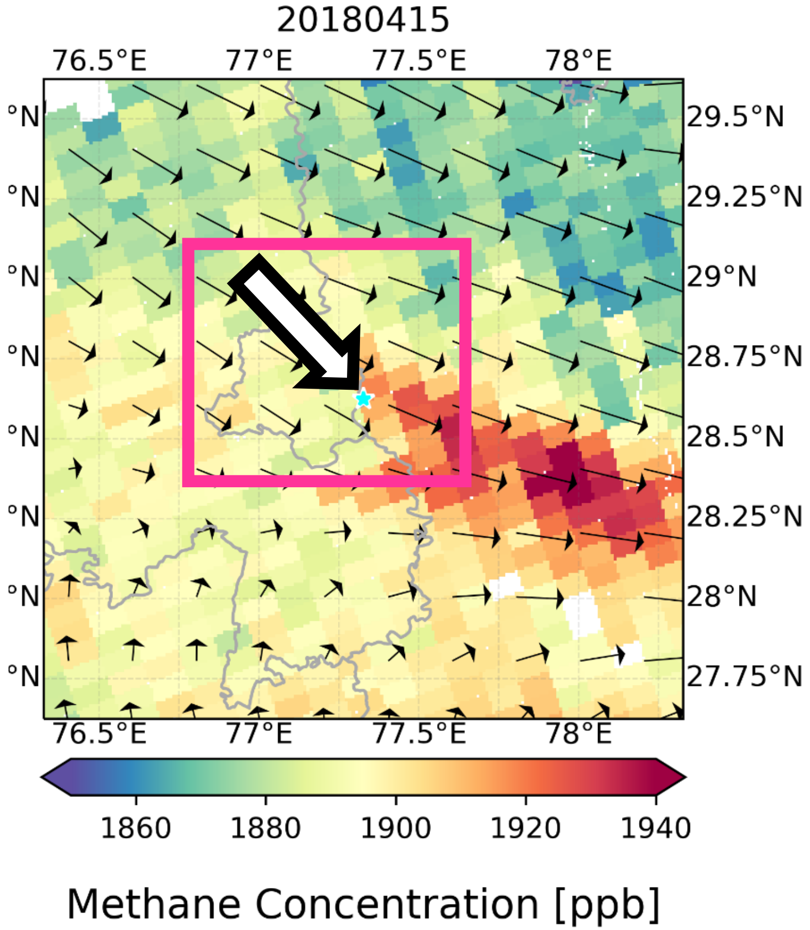
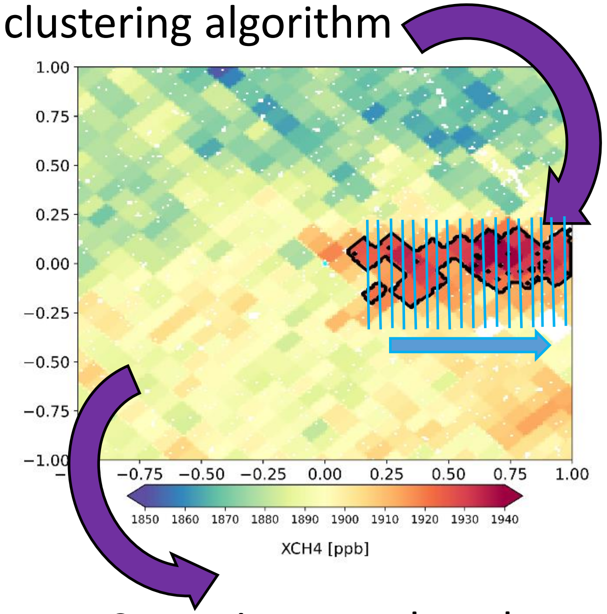
Example: CH_4 over Delhi (Ghazipur)





Enhanced pixels masked as a "plume" by outlier detection and clustering algorithm



Scene is rotated so that plume flows from West to East

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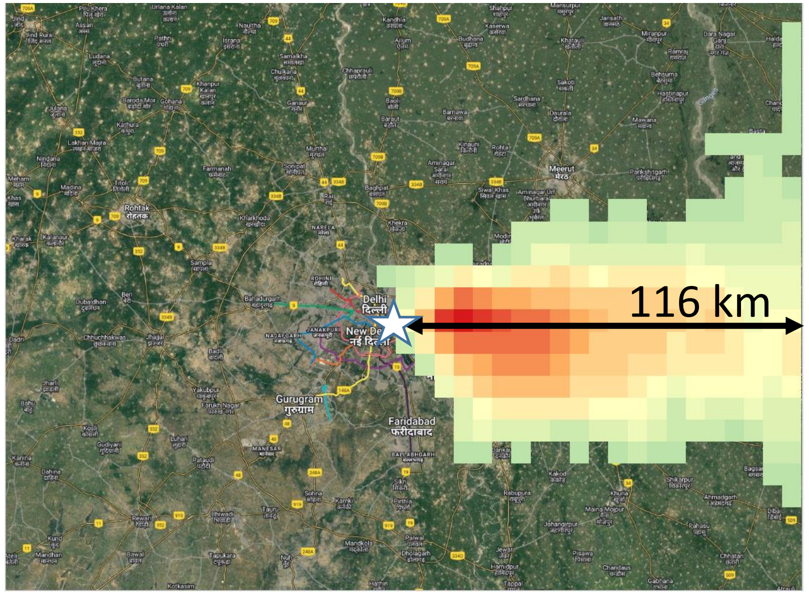
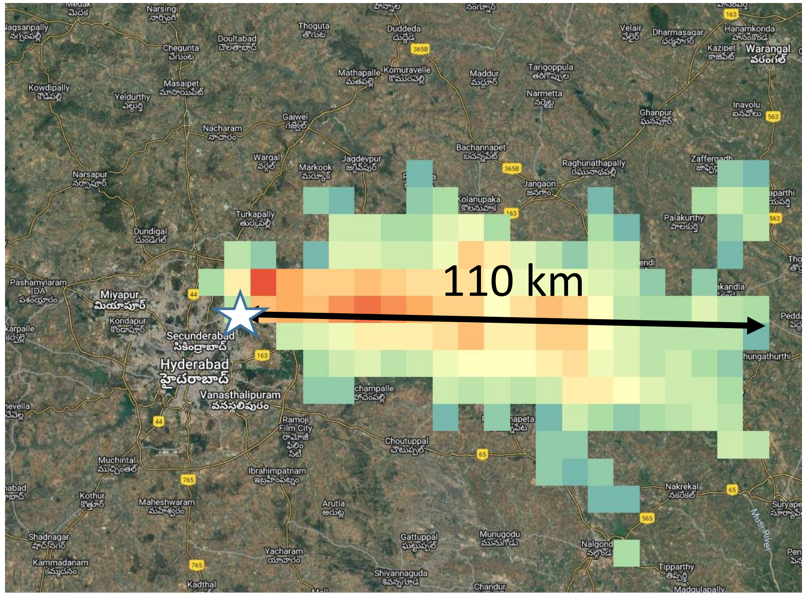
Wind-rotated CH_4 enhancements

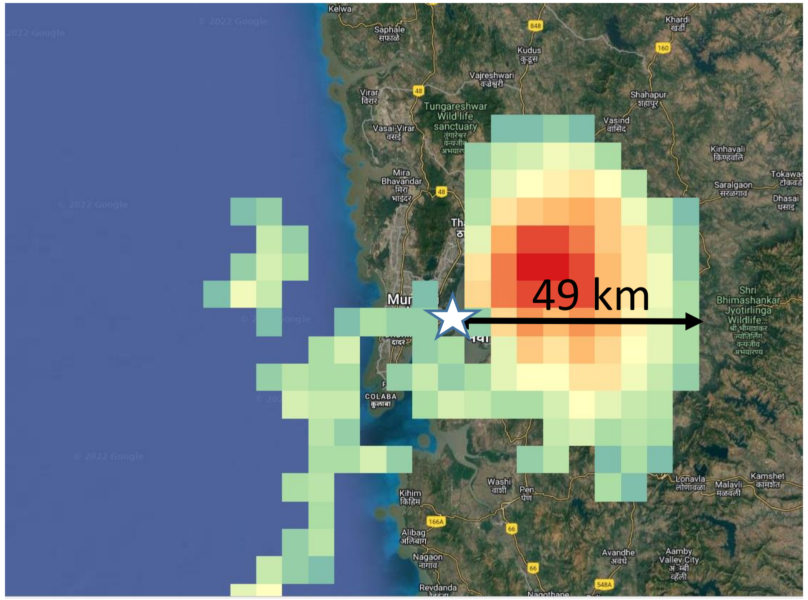
Delhi



Hyderabad



Mumbai



- Rotated, stacked & averaged TROPOMI orbits from 2018/01 to 2020/06
- Largescale features -> cumulative enhancements from many different sources
  -> could be difficult to disentangle signals only landfill emissions

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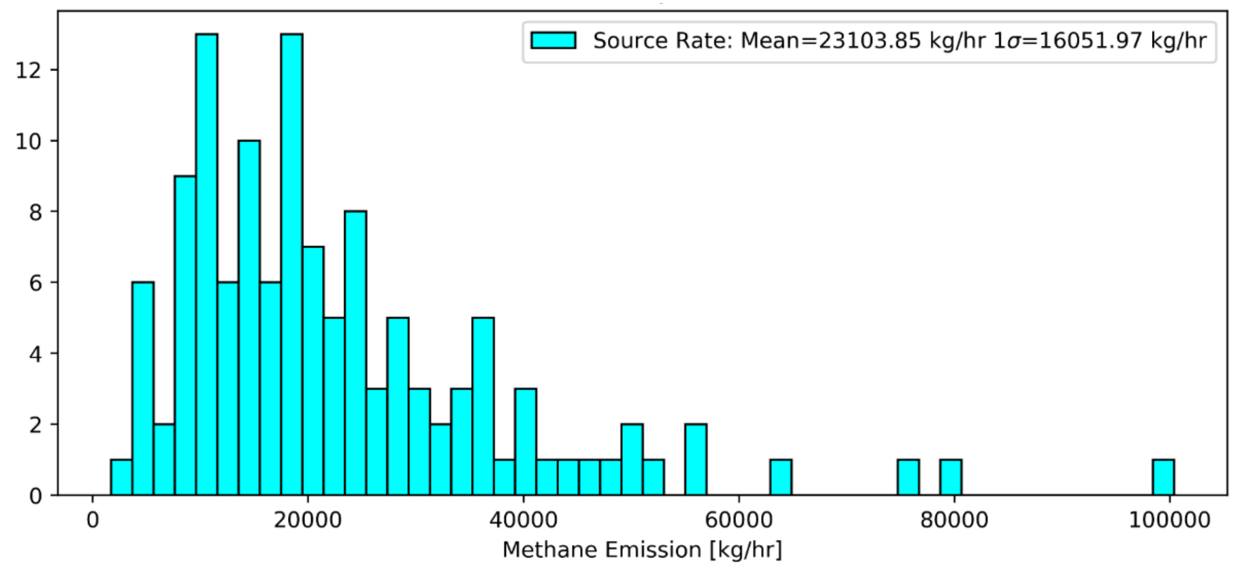
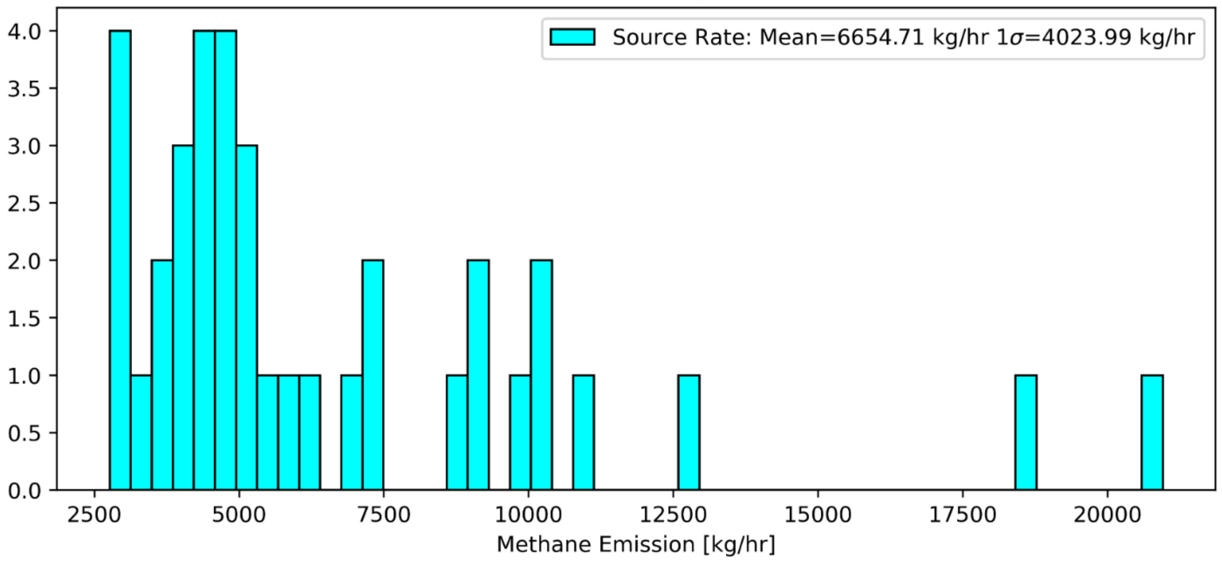
Calculated CH_4 Emissions

Ghazipur Delhi



Jawaharanagar Hyderabad



- TROPOMI orbits analysed from 2018/01 – 2020/06
- Q (source rate in kg/hr) are calculated for individual scenes
- Distribution of the emissions calculated are shown in the histogram

Some anomalously high emission rates calculated –outliers to be discarded

1σ uncertainties in the range of 65 %

Wind speed estimation

Anthropogenic emission contributions

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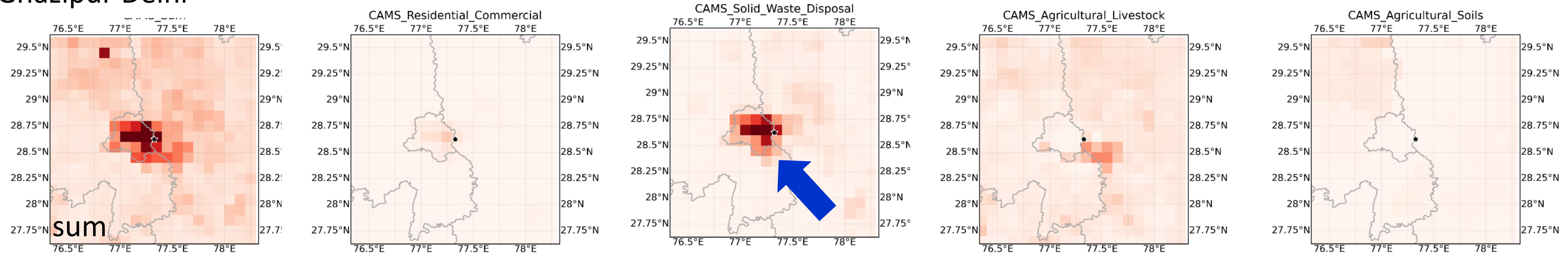
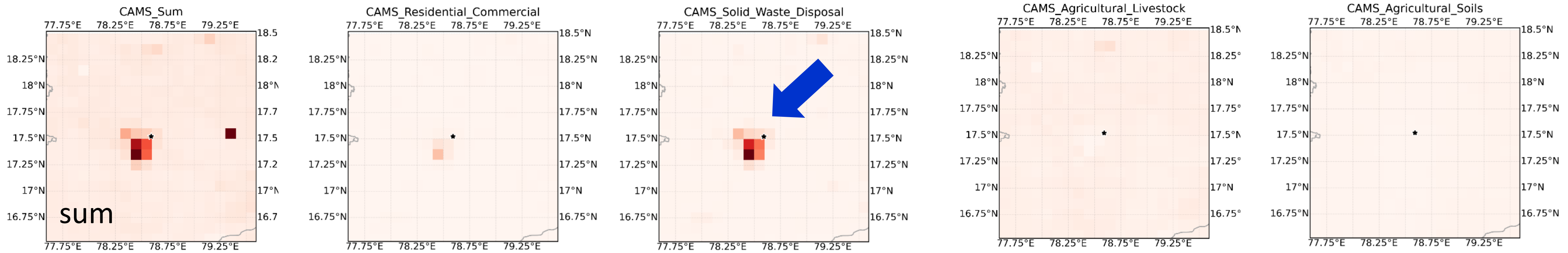
**CAMS anthropogenic methane emissions [kg/hr] – gives an idea of different emission source contributions.*

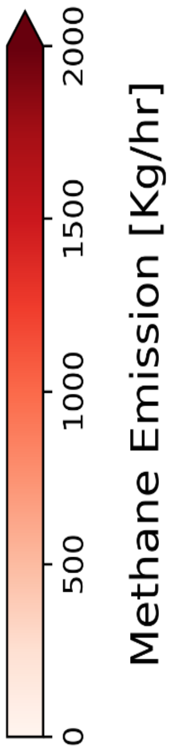
Ghazipur Delhi



Jawaharanagar Hyderabad

Largest source contribution to sum emissions = solid waste disposal





Landfill Site/City/State	*Number of S5p Orbits*	TROPOMI Mean Emission Rate, 1σ & range [Gg/yr]	LandGEM-based modelling studies CH_4 Emissions [Gg/yr] (landfill only)	Kolsepatil et al. 2019 State-level CH_4 Emission [Gg/yr] (w.r.t 2015)	Tropomi-based WRF inversion with EDGAR from Maasakkers et al. 2021 [Gg/yr] (w.r.t 2020)
Deonar/Mumbai	*140*	**235.66 ± 241** (2.5 – 1552)	-	65.506	245 (35% contribution from landfill)
Ghazipur/Delhi	*124*	**202.40 ± 140** (14 – 879)	**12 – 29** [2015: Ghosh et al. 2019] **15 – 29** [2019: Srivastava & Chakma, 2020] **15** [2020: Kumar & Sharma, 2014]	33.936	525 (5% contribution from landfill)
Dhapa/Kolkata	*11*	**109.49 ± 61** (52 – 244)	**15** [2019: Chattopadhyay et. al. 2018]	50.317	-
Tajpur Road/Ludhiana	*35*	**89.30 ± 69** (22 – 350)	-	19.93	-
Jawarahnagar/Hyderabad	*37*	**58.29 ± 35** (24 to 183)	-	4 .0	-

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Summary

- S5p TROPOMI data (2018 -2020) captures enhanced CH_4 features (20 – 70 ppb) over landfill locations in 5 Indian cities
- Emission estimates are larger than those observed in literature
  - Difficulties in disentangling individual landfills from other sources on a city scale (TROPOMI pixels~ 5.5 x7 km^2)
  - Integrated signal more likely captures accumulated CH_4 over time from a multitude of sources over megacities – including landfills contributions

The way forward

- Bringing in complementary sensors like high resolution imagers like GHGsat provides means to pin-point landfill emission and add detail to TROPOMI emission estimates
- Thanks to ESA third party programme, GHGsat has provided targeted observations for each landfill site in 2021/2022
- **Future efforts will be towards making *in situ*/ground measurements** in these locations to get a sense of the spatial heterogeneity and temporal variability of emissions and separate landfill signatures from the wider city contributions
  - Steps towards corrective measures to manage and regulate landfill emissions

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Thank you for your attention.

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