Multi-scale measurements combined with inverse modeling for assessing methane emissions of Hamburg

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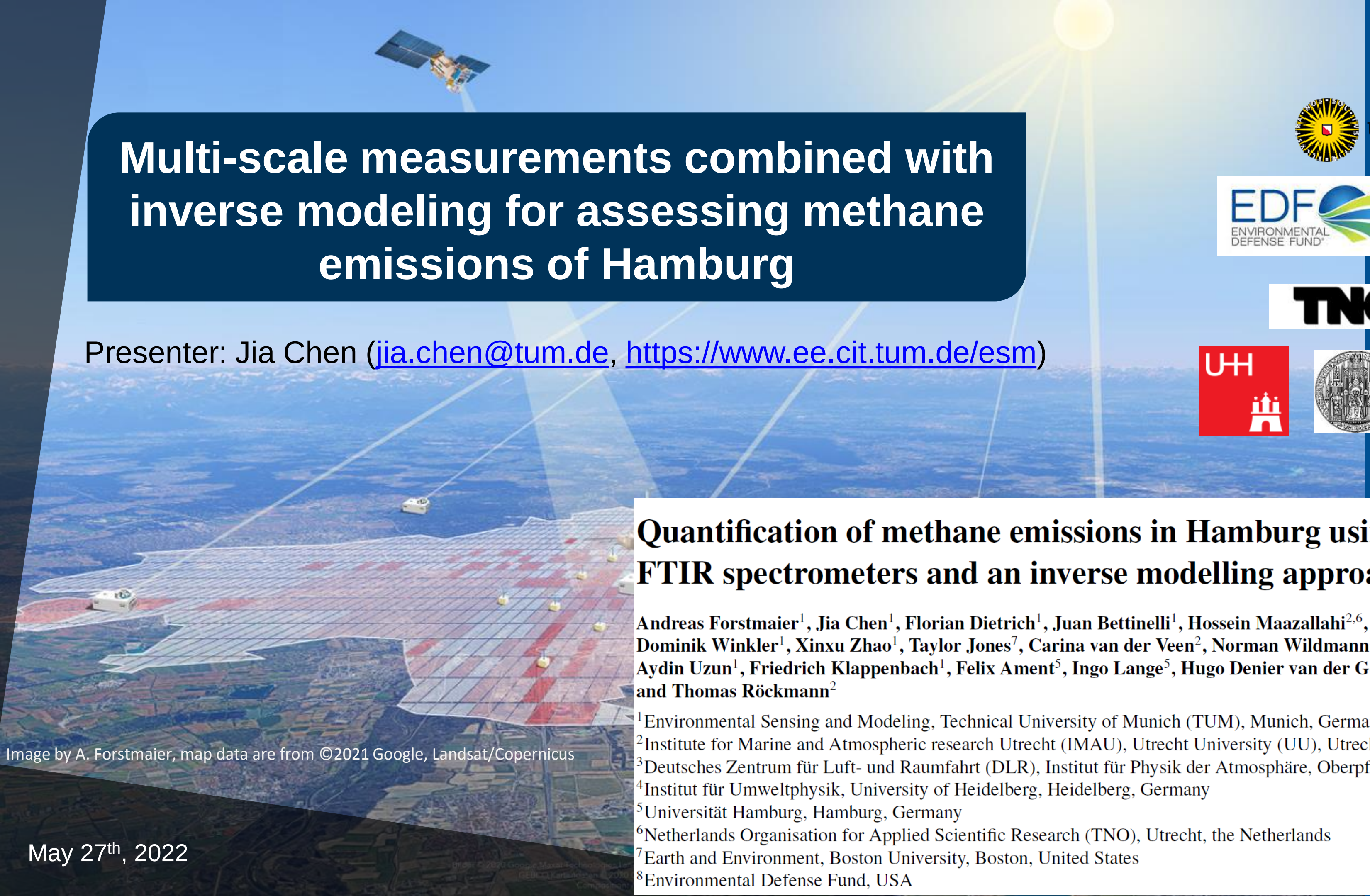

Image by A. Forstmaier, map data are from ©2021 Google, Landsat/Copernicus

Quantification of methane emissions in Hamburg using a network of FTIR spectrometers and an inverse modelling approach

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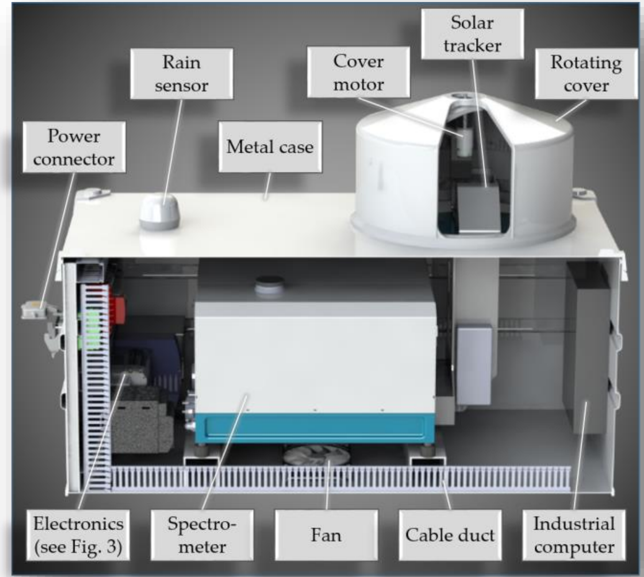
Major components: ground-based remote sensing

(Gisi et al. 2012, Heinle and Chen 2018, Dietrich et al. 2021)

- 4 FTIR sensor systems:
  - EM27/SUN: CH_4 column concentrations
  - Automated enclosure system: Sunny → measure, Rainy → cover close



→ Our system reduces the personnel costs to a minimum and increases the amount of measurement data to a maximum

Heinle and Chen: *Automated Enclosure and Protection System for Compact Solar-Tracking Spectrometers. Atmos. Meas. Tech., 2018*
Dietrich et al.:*Munich permanent urban greenhouse gas column observing network. Atmos. Meas. Tech. 2020*

Multiscale sensor network

- ➢ 4 FTIR systems around high emission zones in Hamburg: upwind/downwind station for arbitrary wind conditions
- ➢ 1 LiDAR system in city center captures 3D wind information → improving transport modeling
- ➢ Isotope measurement → source attribution
- ➢ Mobile Measurements → refining the prior emission inventory

Dietrich, Chen et al.: *MUCCnet: Munich Urban Carbon Column network. Atmos. Meas. Tech., 2021, https://doi.org/10.5194/amt-14-1111-2021*

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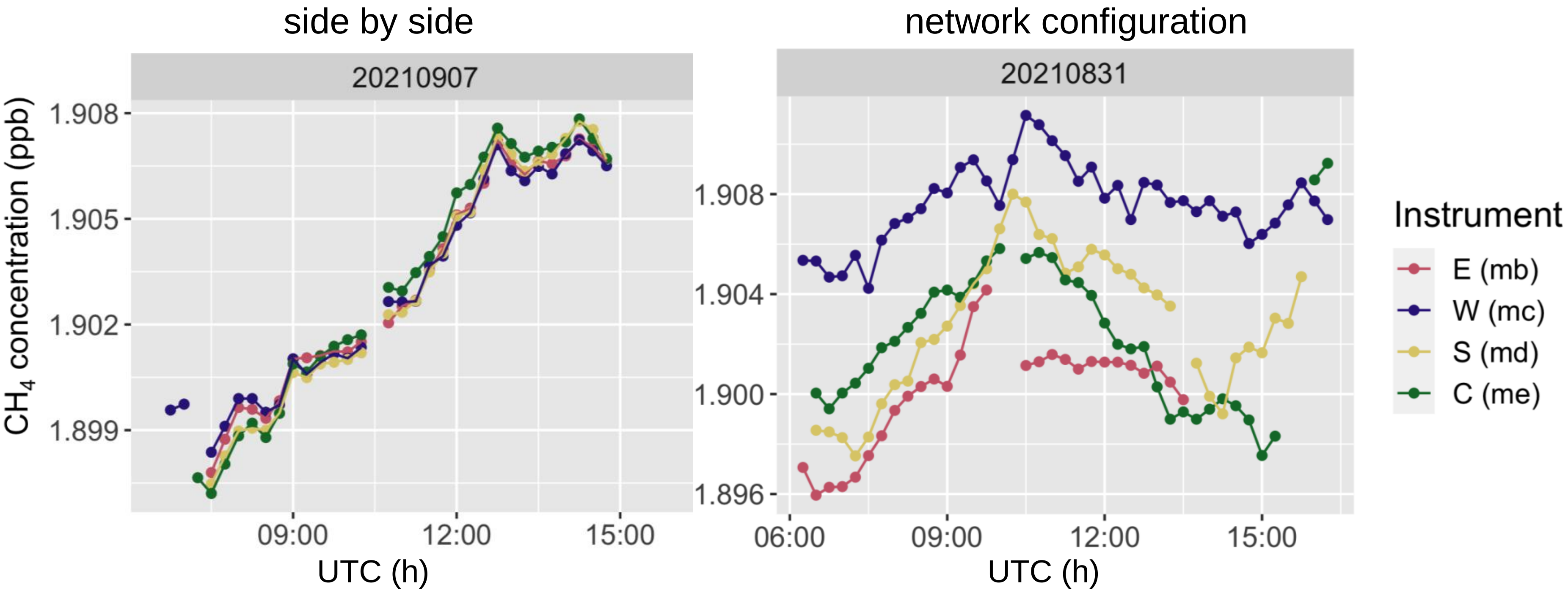
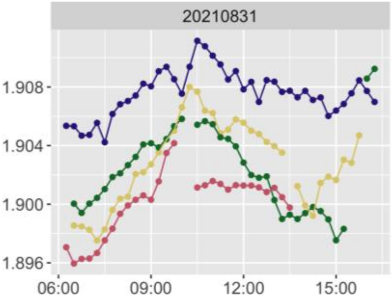
FTIR column measurements

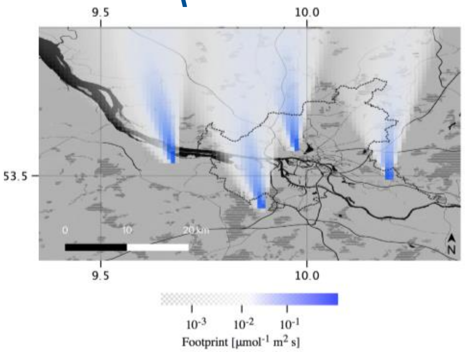


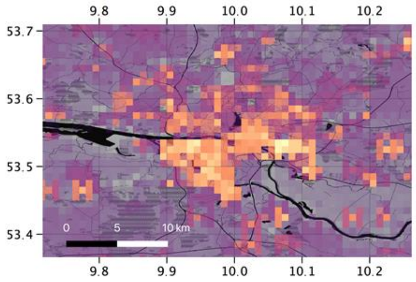
Framework for Estimating Emission (Bayesian Inversion)

(Jones et al. 2021)

$$\min_{x,\,b}\left[(Hx + Bb - y)^T S_\epsilon^{-1}(Hx + Bb - y) + (x_a - x)^T S_a^{-1}(x_a - x)\right]$$







y: *observations*

H: *footprint matrix*

x: *emissions*

x_a: *prior emissions*

B: *background influence matrix*

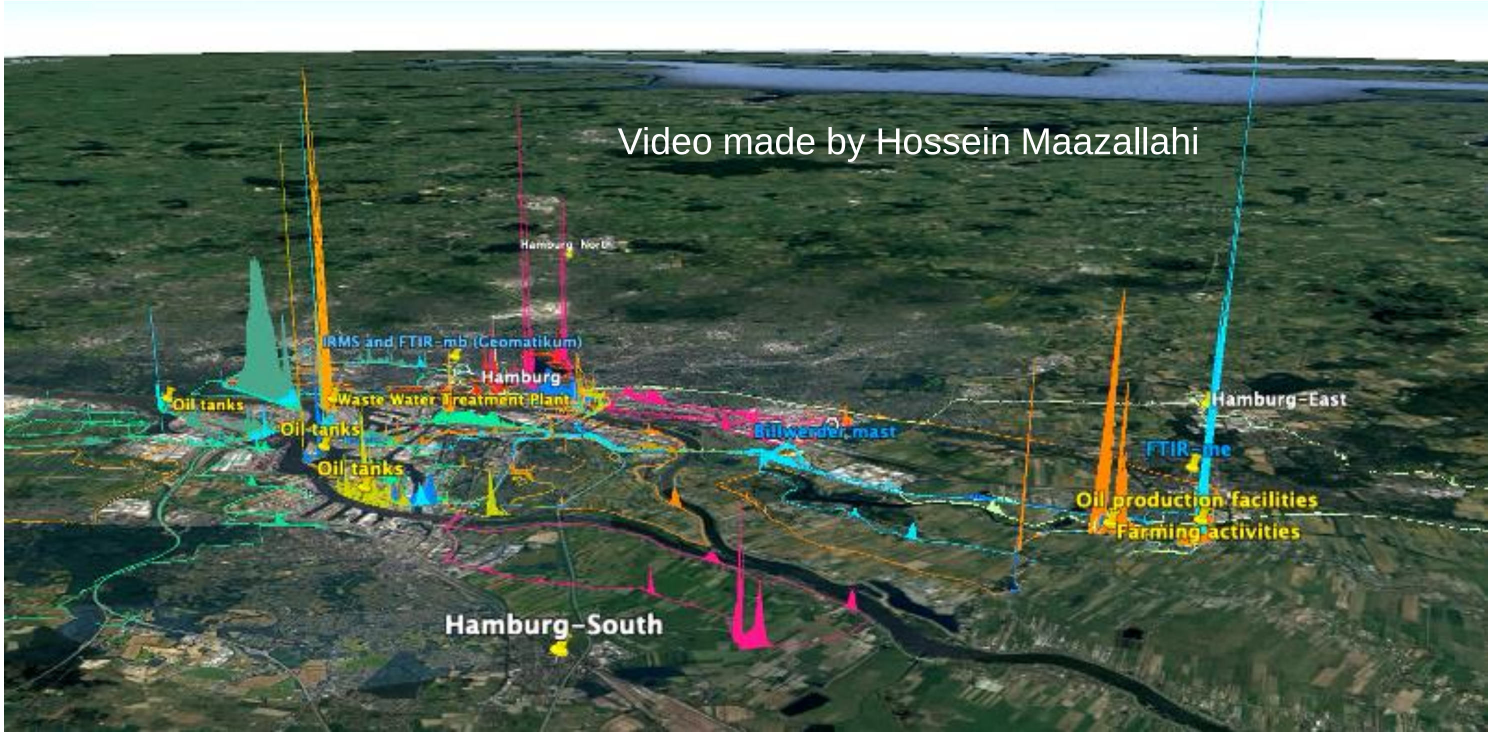
b: *background concentration*

S: *error covariance matrix*

→ Approach: Minimizing a cost function to determine the emissions and the background influence

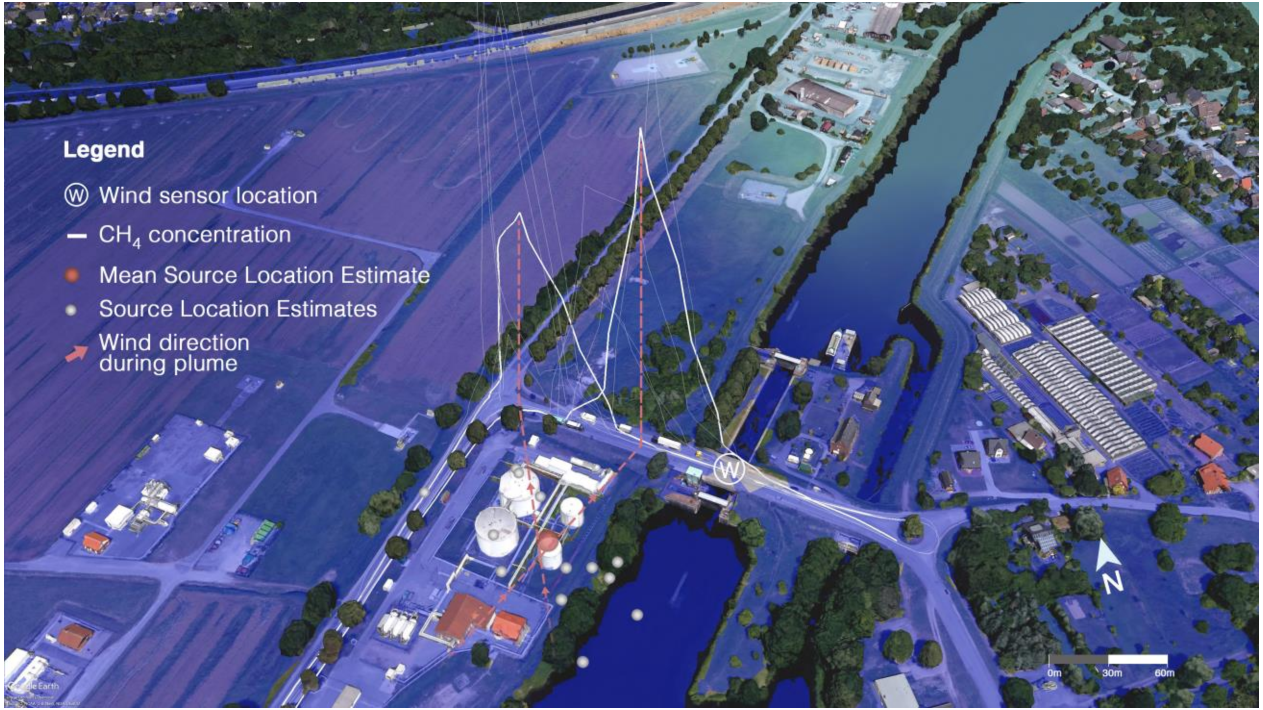
Jones et al.: *Assessing Urban Methane Emissions using Column Observing Portable FTIR Spectrometers and a Novel Bayesian Inversion Framework, Atmos. Chem. Phys., 2021, https://doi.org/10.5194/acp-21-13131-2021*

Mobile measurements



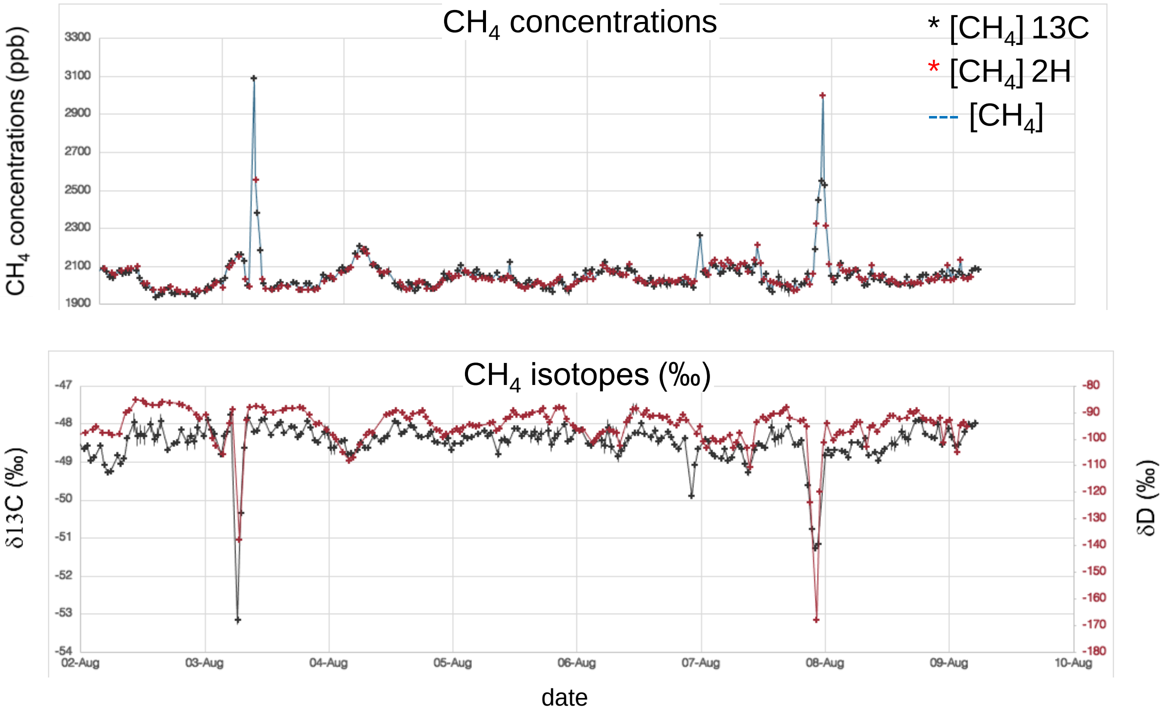
https://youtu.be/LupRJ_h9K5c

Quantification of unknown anthropogenic sources

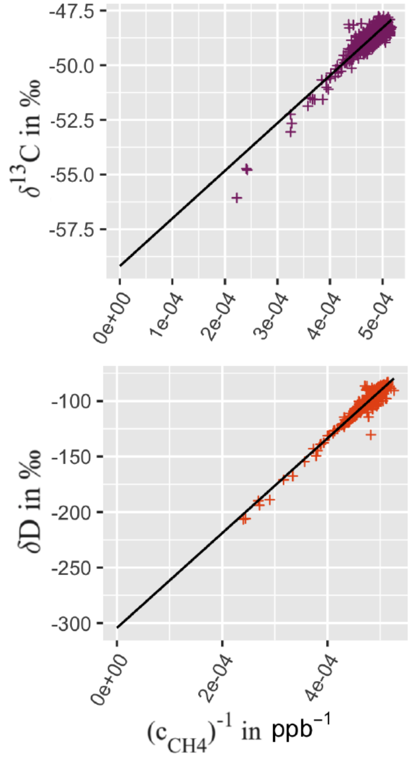


- Unknown point **sources** were detected **in Oil and Gas infrastructure** during mobile survey
- Source strength corrected → up to **100 times** stronger

Indication biogenic sources



Keeling plots



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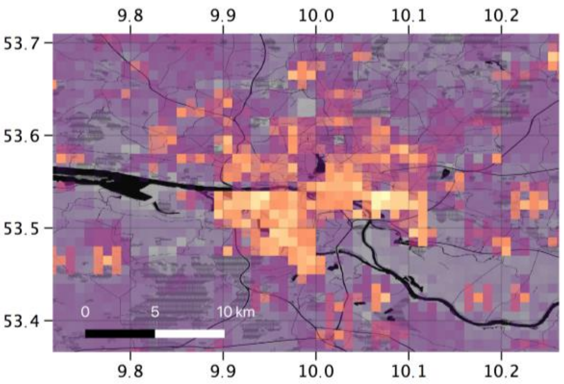
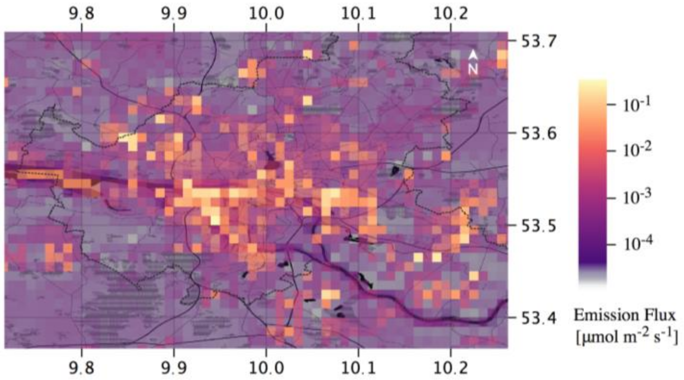
Improving an a-priori emission inventory



Original emission inventory
(e.g. TNO GHGco)

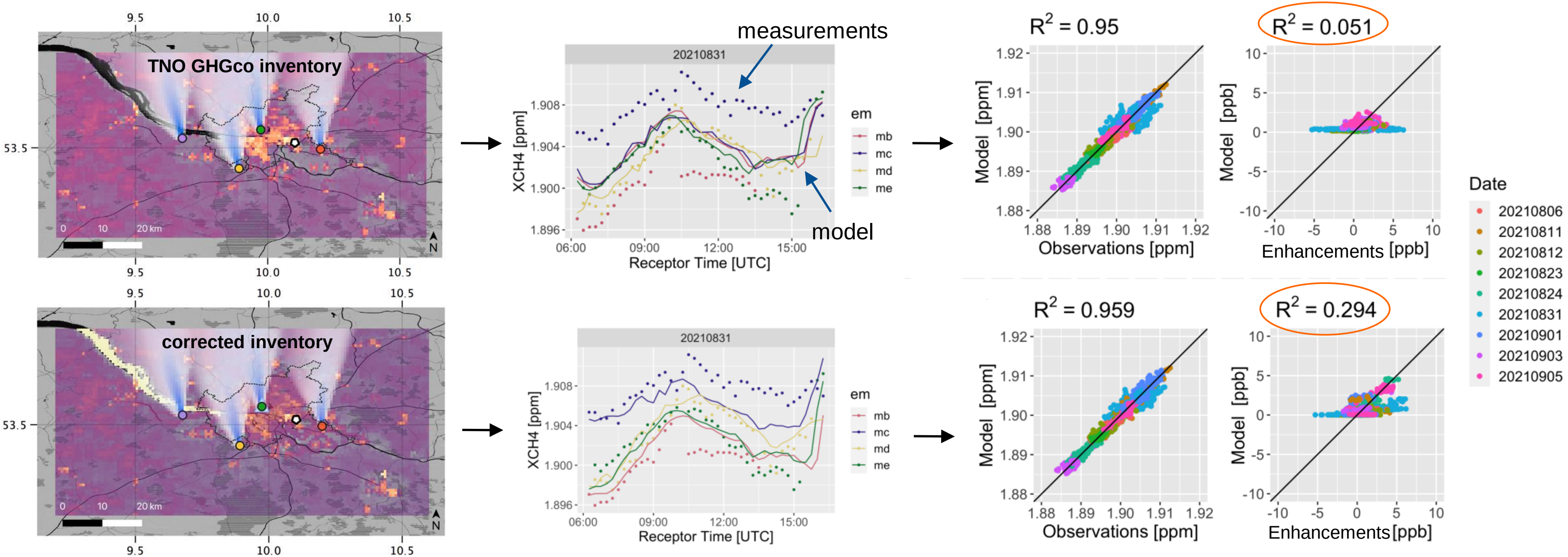
Mobile measurements
(e.g. using Picarro instruments)



Corrected emission inventory

- → Correcting spatial distribution of an emission field using mobile measurements
- → Adding natural sources (the Elbe river and the associated wetlands)

Inversion with unknown sources → modeling improved



Color of river does not match scale of inventory, but amplified for a better visualization.

→ The modelled curves fit the measurements better, correlation of the enhancement improved significantly

Conclusion

- **Unknown sources** in the emission inventory uncovered:
  - Natural sources: Elbe river
  - Antropogenic sources: Refineries, etc.

- **Combination** of ground-based remote sensing and mobile measurements leads to a better inversion

- Hamburg: **Anthropogenic emissions** have largest share; Natural source contribution is significant