Detection of anthropogenic emission point sources of ethylene, propylene, acetylene, and methanol with IASI

B. Franco[1], L. Clarisse[1], M. Van Damme[1,2], J. Hadji-Lazaro[3], C. Clerbaux[3,1], and P. Coheur[1]

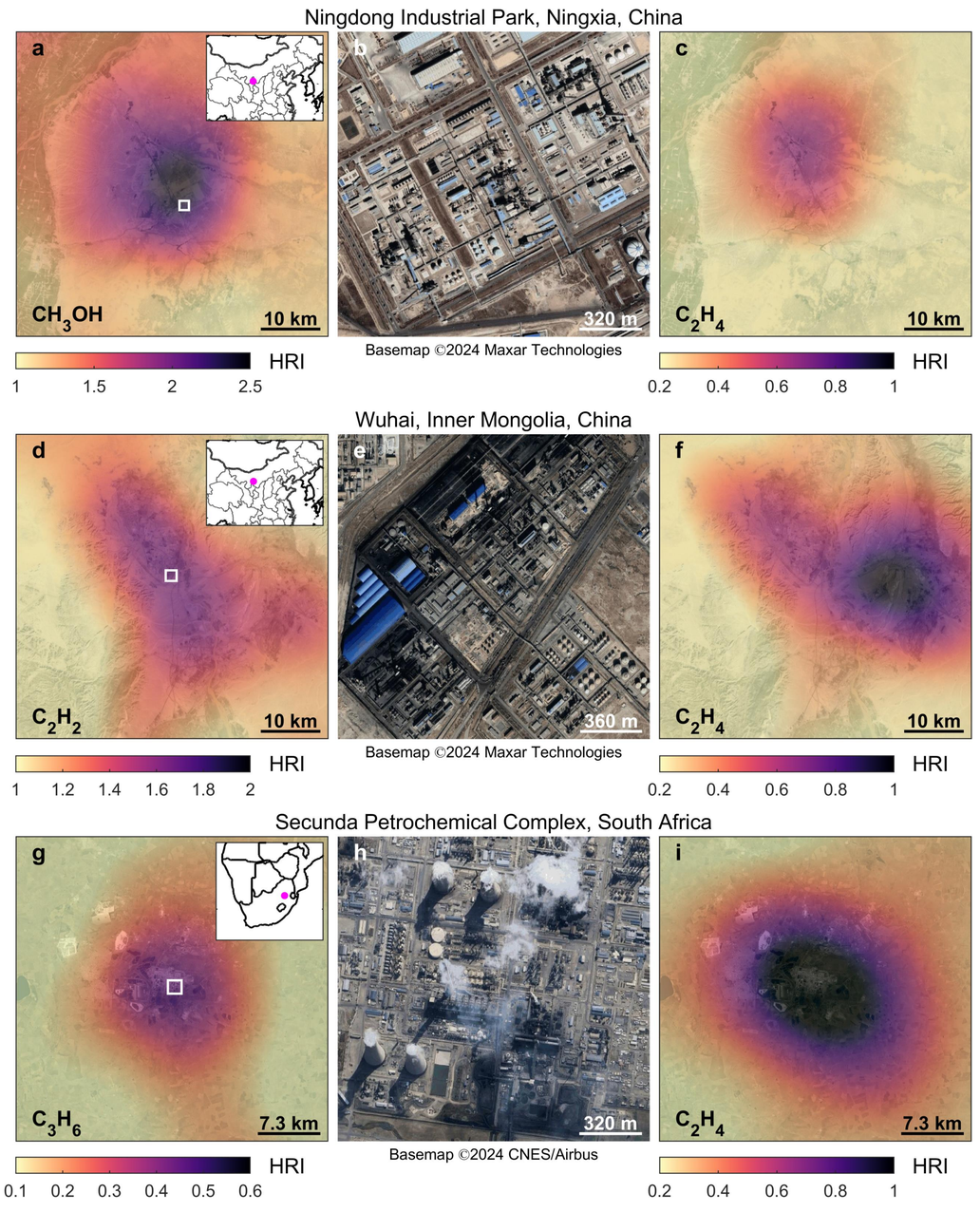
[1]Université libre de Bruxelles (ULB), Spectroscopy, Quantum Chemistry and Atmospheric Remote Sensing (SQUARES), Brussels, Belgium
[2]Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium
[3]LATMOS/IPSL, Sorbonne Université, UVSQ, CNRS, Paris, France
Email : bruno.franco@ulb.be

1. Point source detection

The multi-annual and spatially dense satellite measurements from IASI/Metop offer the opportunity to monitor the atmospheric abundance of non-methane volatile organic compounds (NMVOCs). For each IASI spectrum, we calculated a Hyperspectral Range Index (HRI) to quantify the absorption in the spectrum of major NMVOCs: ethylene (C_2H_4), propylene (C_3H_6), acetylene (C_2H_2), and methanol (CH_3OH).

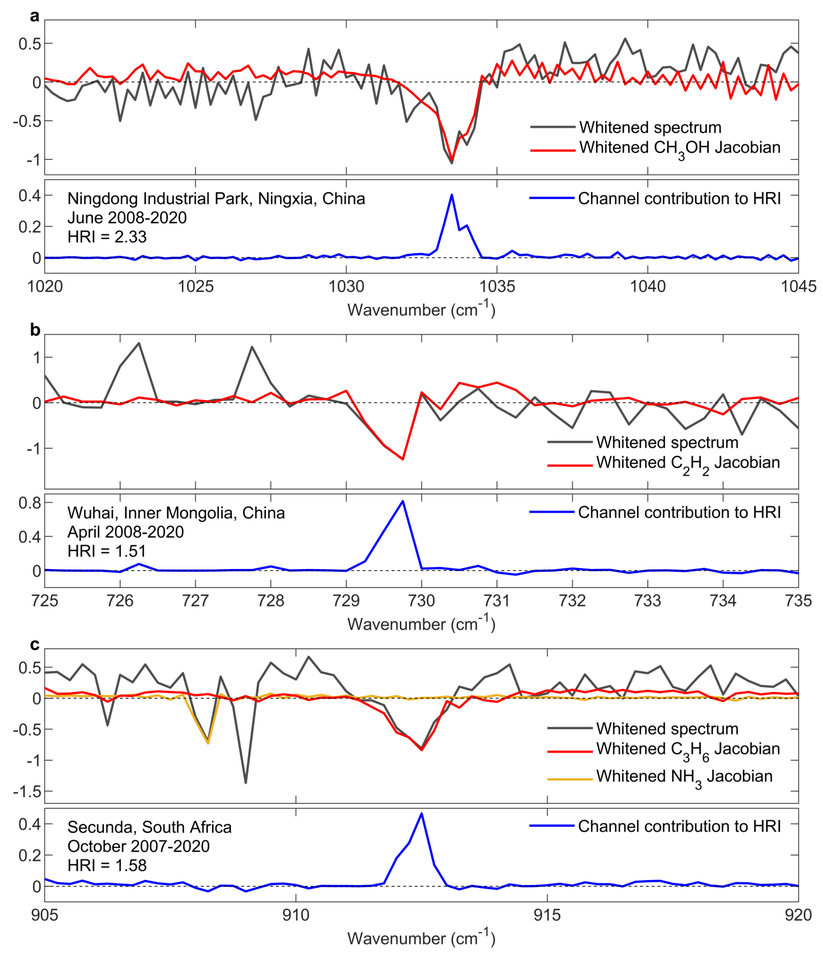
We applied an augmented version of oversampling, the wind-rotated supersampling (Clarisse et al., 2019), to the 2007-2023 IASI NMVOC data. As it resolves much finer spatial features, such technique is effective at locating point sources of a target pollutant that may be challenging or impossible to discern with other averaging techniques.

The wind-rotated supersampled averages of IASI data revealed for the first time anthropogenic point sources of C_2H_4, C_3H_6, C_2H_2, and CH_3OH (Franco et al., 2022, 2024). As shown in the examples on the right, these point sources are associated with heavy industrial activities.



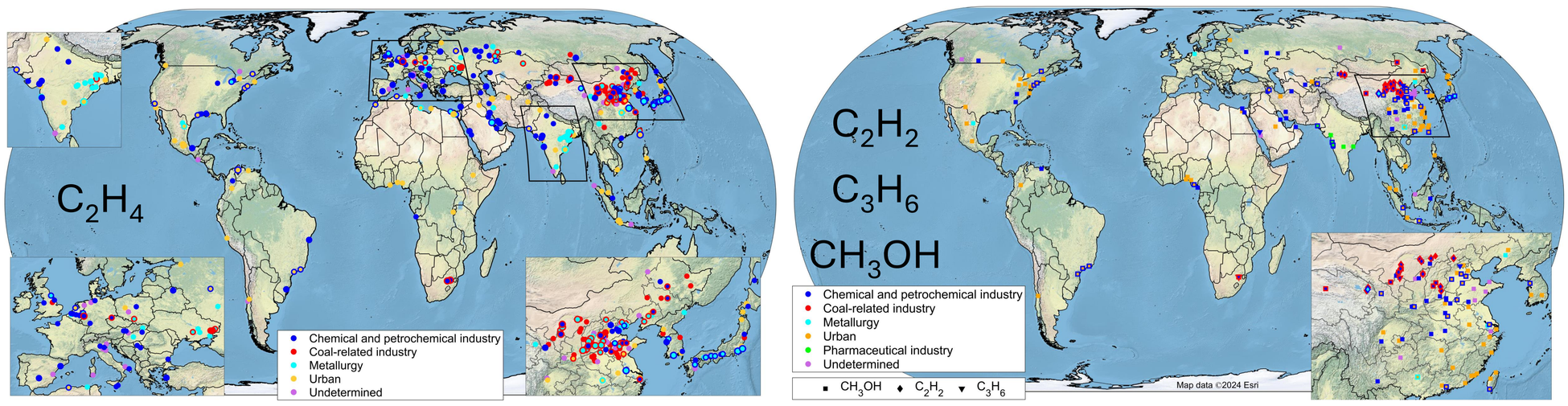
2. Spectral evidence

Since the HRI is prone to false detections, we applied a whitening transformation (De Longueville et al., 2021) to IASI spectra over detected hotspots, as shown in the figure below. This process highlights the contribution of the target species to the signal recorded in the spectra and provides firm evidence that the elevated HRI values observed over the hotspots correspond to actual enhancements of CH_3OH, C_2H_2, C_2H_4, and C_3H_6.



3. Anthropogenic point sources

We analysed the hyperfine-resolution global distribution produced by supersampling for each target species, revealing anthropogenic point sources: 336 for C_2H_4, 157 for CH_3OH, 16 for C_2H_2, and 4 for C_3H_6. As observed on the maps below, the highest concentration of NMVOC point sources is found in eastern Asia.



For each point source, we used visible satellite imagery and online data regarding the types of companies and industrial activities in the area to determine the likely gas emitter(s).

The point sources correspond to five main types of emitters:

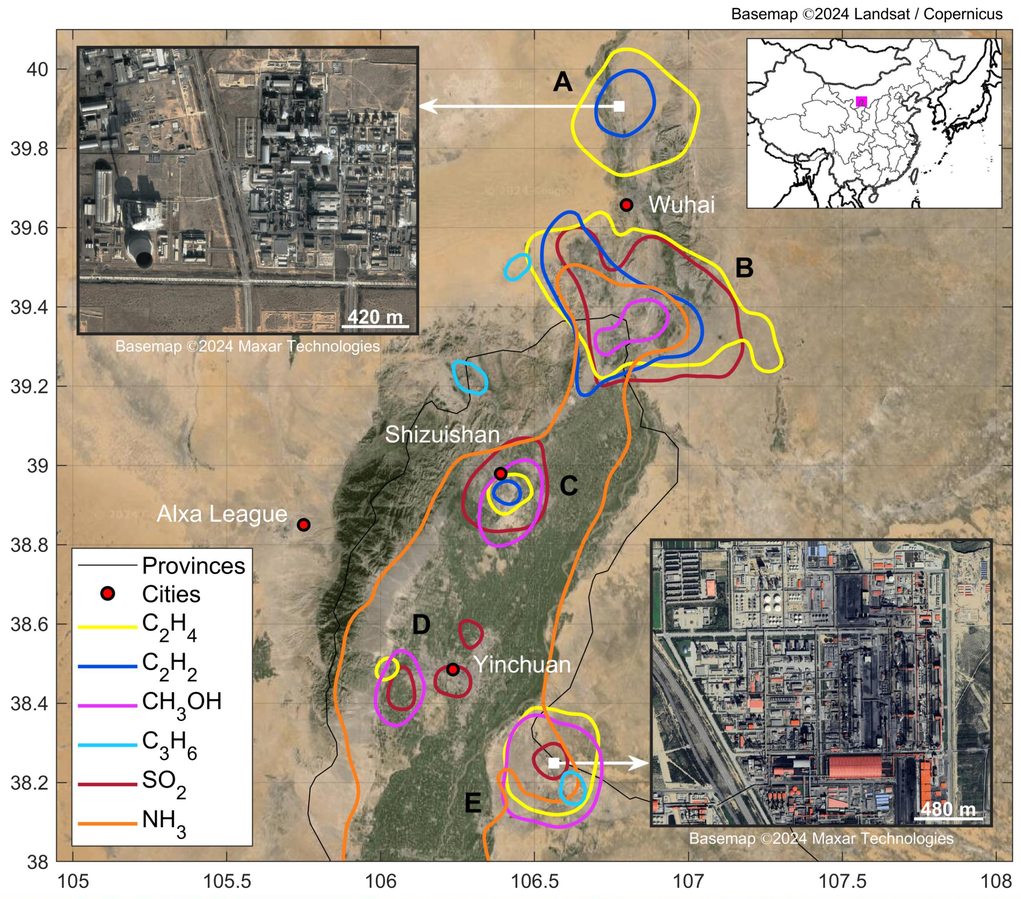
- **chemical and petrochemical industry** (e.g., petrochemical hubs)
- **coal-related industry** (e.g., coal-fired power plants, coal mining, coke plants)
- **metallurgy** (e.g., iron and steel plants)
- **urban** (megacities)
- **pharmaceutical industry** (pharmaceutical production facilities)

4. Combining organic and inorganic tracers

While satellite measurements have become valuable tools for tracking anthropogenic emitters, they have primarily targeted inorganic species (NO_2, SO_2, and NH_3) and methane. This work demonstrates that combining organic and inorganic tracers to study anthropogenic emissions can provide more insights into the largest gas emitters and help identify the most polluted areas for further dedicated measurements.

As a case study, the figure on the right presents the supersampled distributions of C_2H_2, C_2H_4, C_3H_6, and CH_3OH, as well as those of SO_2 and NH_3 from IASI (Clarisse et al., 2019; Van Damme et al., 2018), depicted as contour plots, over an industrial valley in the Inner Mongolia and Ningxia provinces, central China. These distributions reveal a significant cluster of gas hotspots concentrated around five locations.

While SO_2 and NH_3 enhancements point to emissions from coal-fired power plants, coal refining, and agriculture, the NMVOC data suggest releases from chemical and petrochemical facilities, iron and steel plants, and dense urban areas, complementing the information provided by the inorganic species.



Acknowledgements

This research is supported by ESA through the World Emission project (contract No. 4000137291/22/I-EF): https://www.world-emission.com. Activities at ULB have also been supported by the HIRS PRODEX arrangement (ESA–BELSPO). L. Clarisse is a research associate supported by the F.R.S.–FNRS.

References

- Clarisse et al. (2019) *AMT*, 12, 5457–5473, doi:10.5194/amt-12-5457-2019
- De Longueville et al. (2021), *GRL*, 48, e2020GL091742, doi:10.1029/2020GL091742
- Franco et al. (2022) *Nat. Commun.*, 13, 6452, doi:10.1038/s41467-022-34098-8
- Franco et al. (2024) *in preparation*
- Van Damme et al. (2018) *Nature*, 564, 99–103, doi:10.1038/s41586-018-0747-1