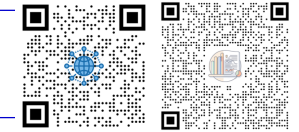


ADECEES: Anomaly Detection of CO₂ Emissions via Ensemble Segmentation

Andrianirina Rakotoharisoa^{1,2}, Simone Cenci³, Rossella Arcucci^{1,2}



Motivation

- Anthropogenic emissions of greenhouse gases (GHGs) play a significant role in global warming. CO₂ specifically is responsible for a 0.8°C (0.5°C–1.2°C) historical increase [1].
- Most studies focus on the quantification of CO₂ emissions from known sources. The topic of CO₂ point source detection and discovery remains relatively unexplored.

We propose a multi-purpose CO₂ emissions monitoring system, ADECEES for the detection of point sources and the study of change in emissions. It segments high CO₂ concentration zones attributable to point sources.

Data processing

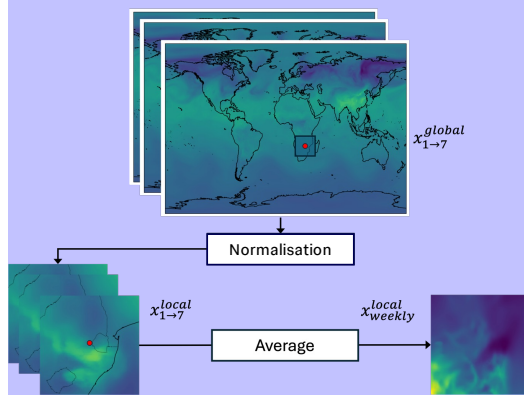


Figure 3: Preprocessing pipeline. $x_{1 \rightarrow 7}^{global}$ represent daily global XCO₂ maps. The targeted area is selected before being normalized and averaged over a week to produce $x_{1 \rightarrow 7}^{local}$.

Anomaly Detection System

Partial Diffusion

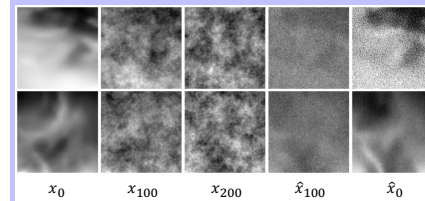
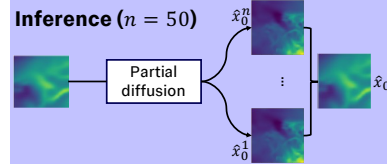


Figure 1: Partial diffusion process. x_0 is partially corrupted until a timestep λ (here $\lambda = 200$) and diffused to create \hat{x}_λ .

Inference ($n = 50$)



Segmentation (threshold $t = 0.7$)

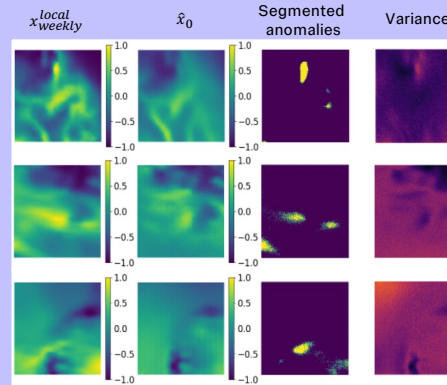


Figure 2: Anomalies detected after inference and segmentation.

Results

- ADECEES can detect new point sources
- Performance of the system depends on location
- Emissions' variations are reported by the system
- Impact of emissions on surroundings can be visualised

	Mine 1 (Bg.)	Mine 2 (Ot.)	Mine 3 (Iv.)	Mine 4 (Hw.)
Acc.	0.60	0.90	0.40	0.70
Prec.	0.60	1.00	0.43	0.67
Recall	0.60	0.80	0.60	0.80
F1-Sc.	0.60	0.89	0.50	0.73

Table 1: Metrics for the detection of coal mines through emissions of CO₂.

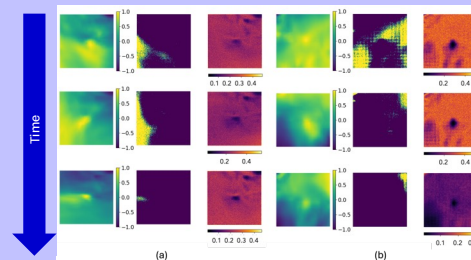
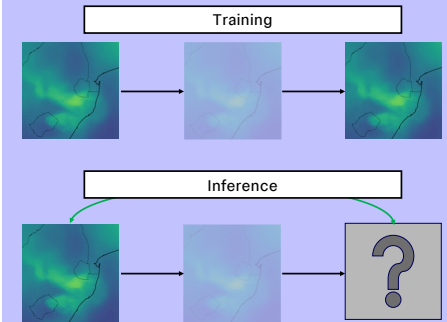


Figure 4: Temporal evolution of emissions as detected by ADECEES for powerplants in Germany (a) and Texas, US (b).

Dataset & Training

- Global daily dataset XCO₂ dataset [2]
- One iteration of the system per location
- Training is composed of emission free samples



Main Takeaways

- Implementation of an end-to-end CO₂ emissions detection system
- The system can be applied to multiple problems: point source detection or monitoring of emissions' variations

Future works

- Identify the threshold above which the system is capable of detection
- Consider additional variables for diffusion reconstruction

[1]: Yang Ou, Gokul Iyer, Allen Fawcett, Nathan Hultman, Haewon McJeon, Shaun Ragnauth, Steven J Smith, and James Edmonds. Role of non-CO₂ greenhouse gas emissions in limiting global warming. *One Earth*, 5(12):1312–1315, 2022.

[2]: Andrianirina Rakotoharisoa, Simone Cenci, and Rossella Arcucci. A high resolution spatially consistent global dataset for CO₂ monitoring. *Remote Sensing*, 17(9):1617, 2025.