Co-ordinated by ECMWF

CoCO2
Prototype system for a Copernicus CO_2 service

USING SATELLITES AT THE CITY SCALE

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The road to estimating CO_2 fossil fuel emissions from space

We do not see CO_2 emissions directly from space, but we can see the CO_2 plumes.

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Since CO_2 accumulates in the atmosphere, relative variations of the CO_2 columns are ~ 1 %.

Need much higher accuracy than these typical variations

- Target random errors ~ 0.25 %
- Target systematic errors ~ 1 ‰

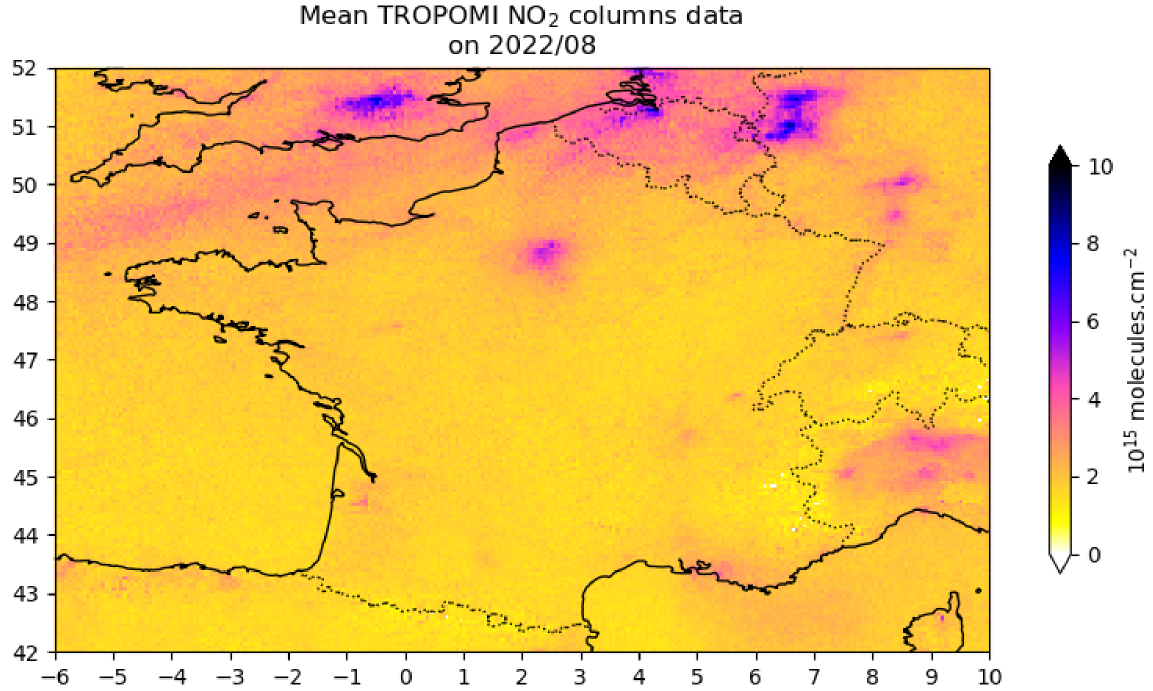
Further, we need information about CO_2 in the lowest layers

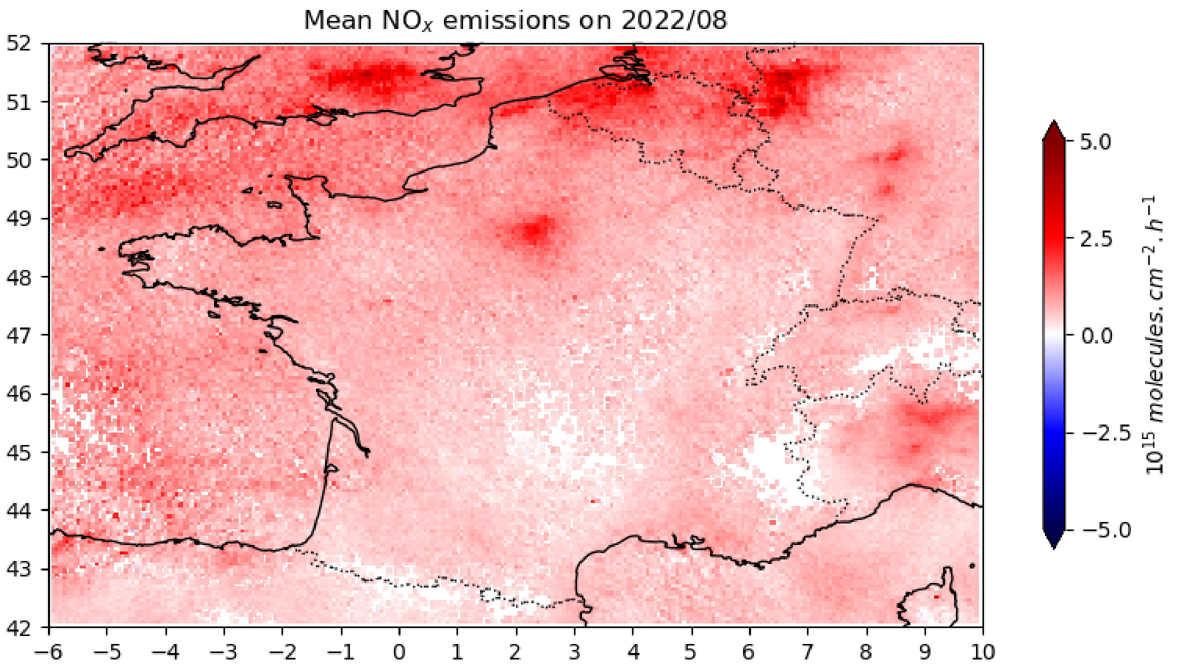
- Use reflected sunlight
- Clear sky, daytime

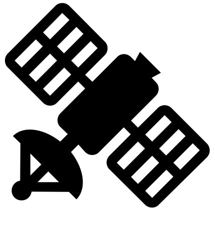
The remote sensing of CO_2 is pushing the limits of remote sensing in general.

- First CO_2-dedicated satellite launched in 2009 only (Japan)
- The situation is slightly less challenging for CH_4 linked to a larger relative variability

Pollution emissions seen and quantified from space - TROPOMI







Number of NO_2 molecules → Emission rate of NO_x

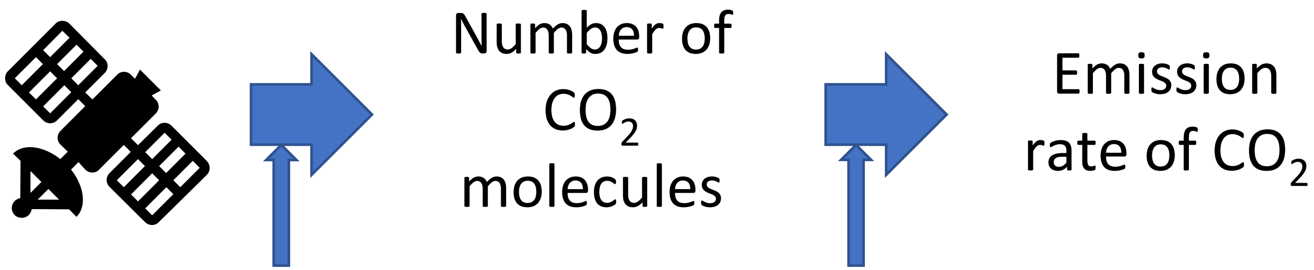
S5P/TROPOMI: satellite+instrument operated by ESA since 2017, polar orbit, large swath (2600 km). **Ground resolution = 19 km²**. NO_2 column estimated in **clear skies, sunlit**.

Images from A Heraud (LSCE) after Rey-Pommier et al. (2022)

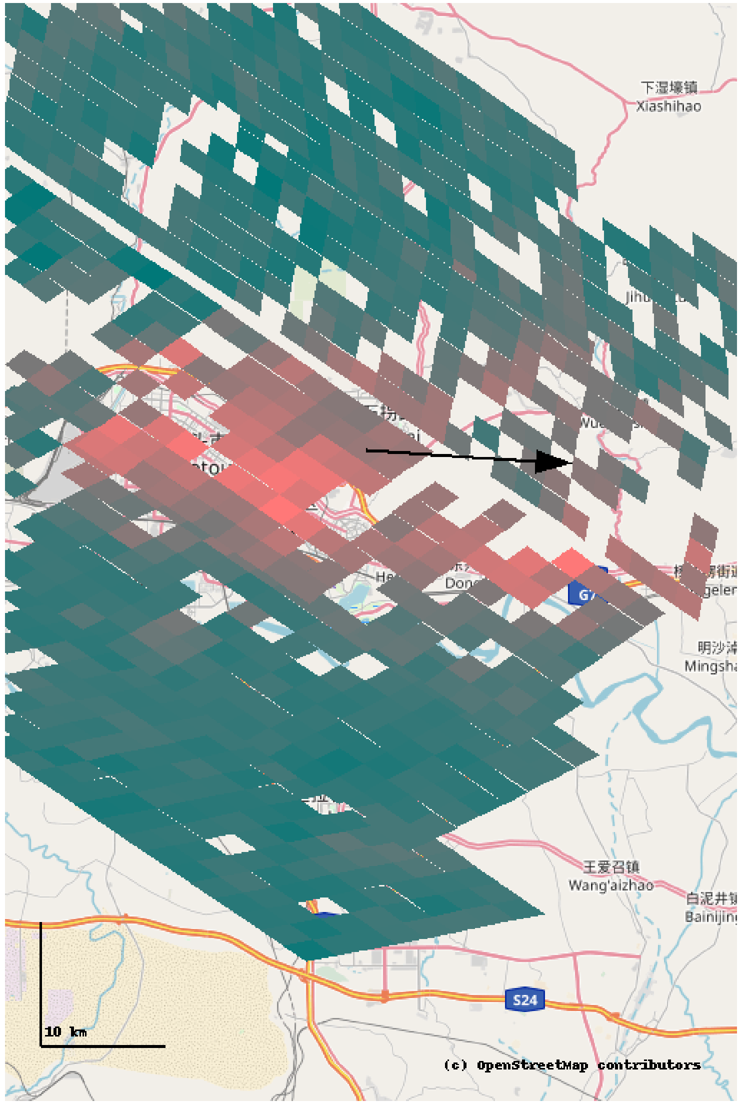
CO_2 emissions seen and quantified from space – OCO-2

OCO-2: satellite+instrument operated by NASA since 2014, polar orbit, narrow swath. **Ground resolution = 3 km²**. **Column-average** CO_2 concentration estimated in **clear skies, sunlit**.

OCO-2 orbit track East of Ningdong city, China, 16 November 2022, early afternoon.
The arrow indicates the estimated wind direction close to the surface.

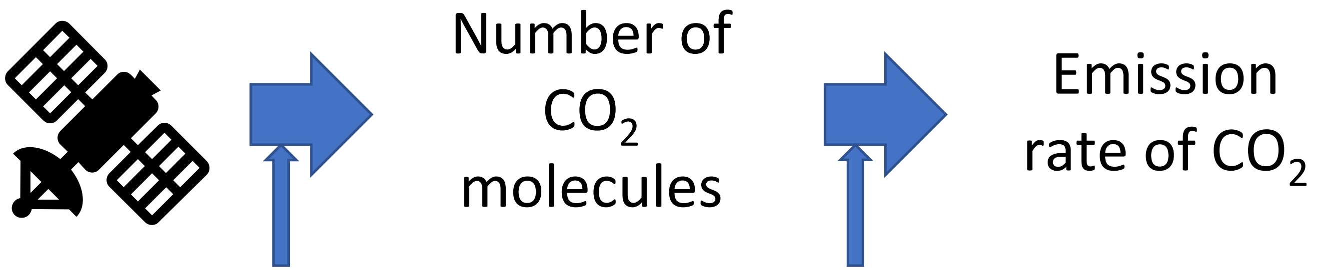


CO_2 emissions seen and quantified from space – OCO-3

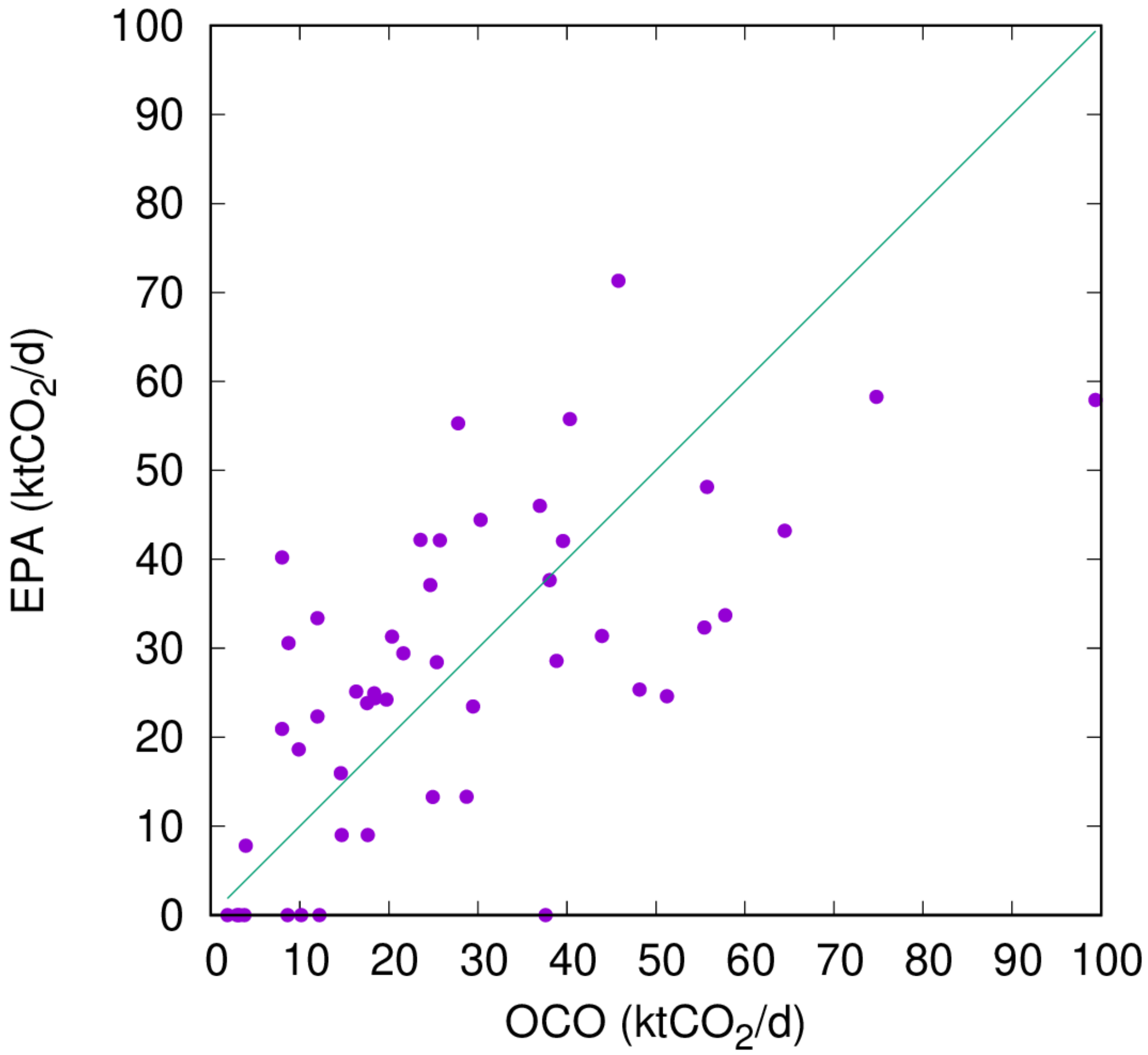


OCO-3: instrument operated by NASA onboard the International Space Station since 2019, narrow swath but a same scene can be scanned successively several times. **Ground resolution = 3 km²**. **Column-average** CO_2 concentration estimated in **clear skies, sunlit**.

OCO-3 orbit track East of Baotou city, China, 21 October 2022, early afternoon.
The arrow indicates the estimated wind direction close to the surface.



CO_2 emissions seen and quantified from space – OCO-⅔

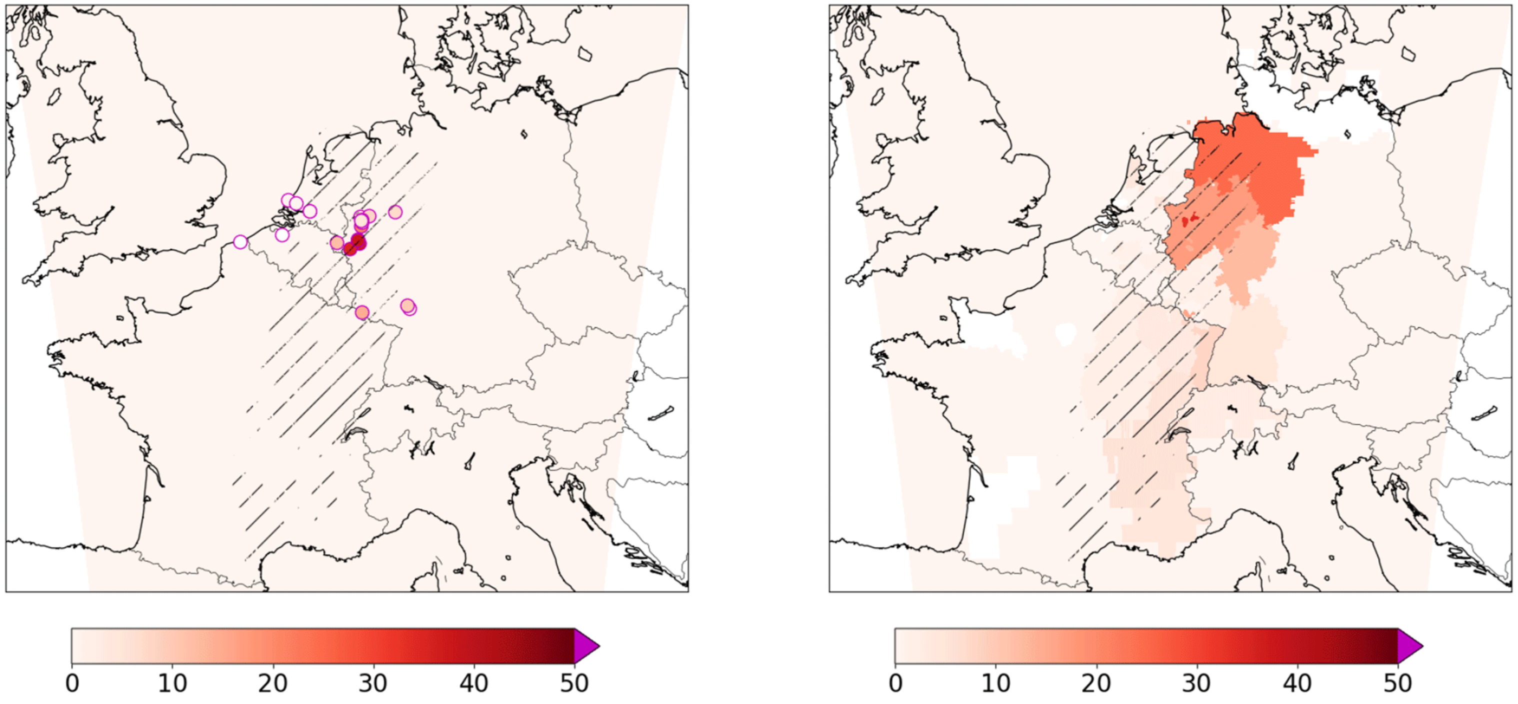


Emission estimation
+ quality control
+ spatial disaggregation.

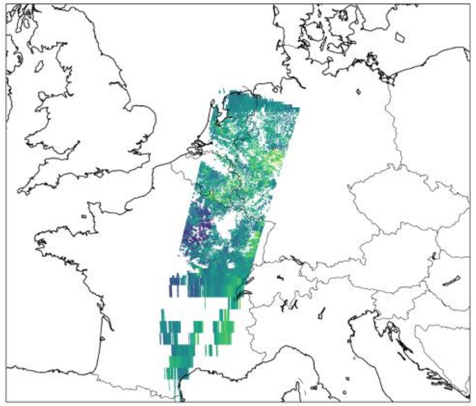
- ❑ 49 individual cases of coal-fired power plants in the USA in the OCO archive (after QC).
- ❑ Comparison of the emission estimates to the numbers reported by the U.S. Environmental Protection Agency (EPA). **Differences are mostly random** (wind direction, etc.).
  - ○ Spread (1 sigma) = 54%.
  - ○ Bias = 1%.

After Chevallier et al. (2022)

CO_2 emissions seen and quantified from space – CO2M



(a) FF PS (b) FF other



CO2M: constellation of satellite+instrument operated by ESA starting in 2026. Takes the best of TROPOMI (swath) for CO_2. CO_2 column estimated in **clear skies, sunlit**.

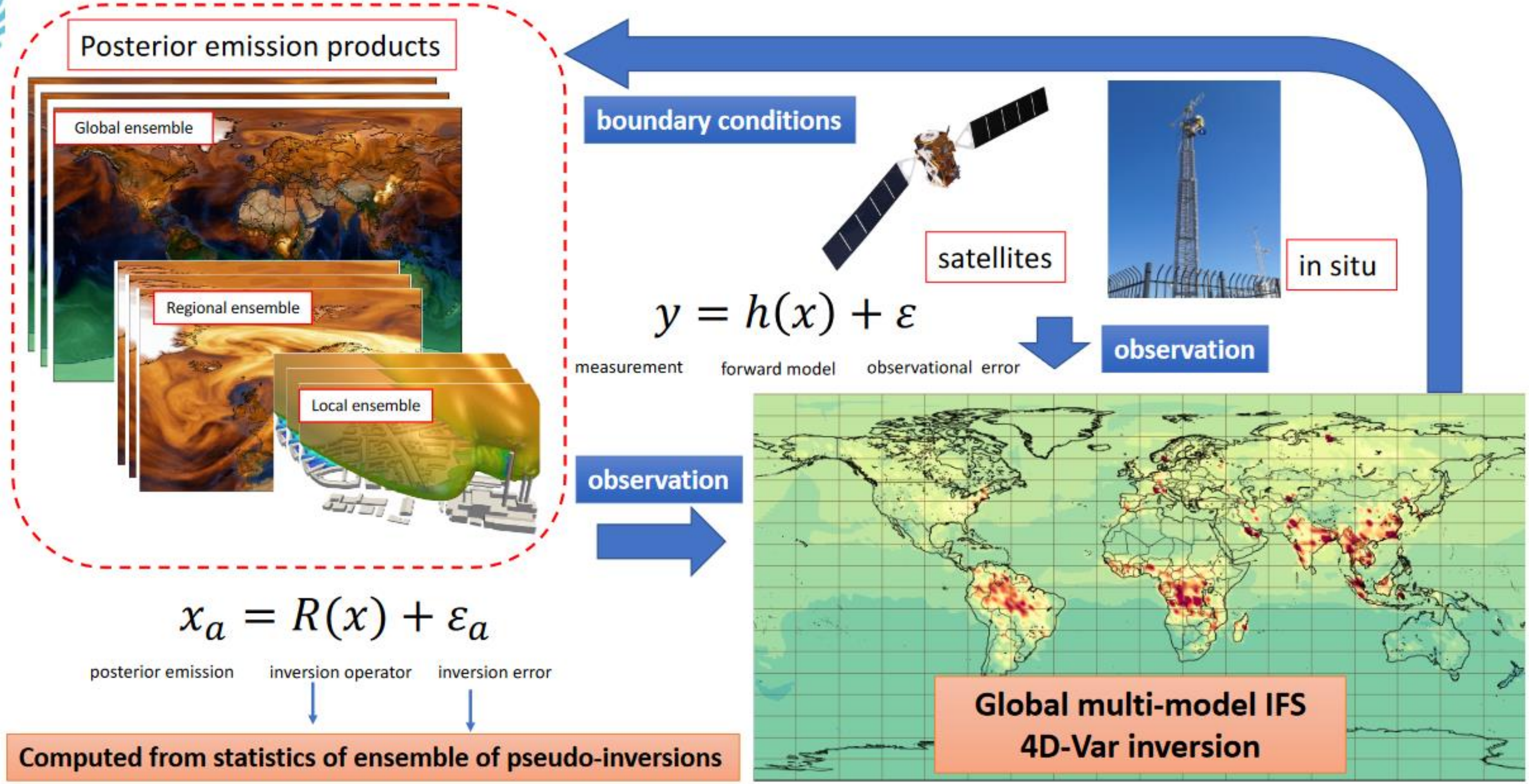
Expected uncertainty reduction (%) after one CO2M July orbit at 12:00 UTC

(a) Morning emissions of large industrial plants (goes > 50%)

(b) Other morning fossil fuel emissions (goes to ~ 30%)

From Potier et al. (2022)

Multi-model multi-scale approach



Summary and prospects

- ✓ So far, CoCO2 has put the priority on CO_2 emissions rather than CH_4
  - Toughest problem
- ✓ **We have exceeded expectations** for the estimation of CO_2 fossil fuel emissions based on existing instruments that were not designed for this purpose.
- ✓ **Large random noise but low bias**: we can robustly compute trends if we average over large amounts of data

Summary and prospects

- ✓ CO2M will provide several orders of magnitude of additional data: we expect emission estimates to have **a low random noise and a low bias**
- ✓ Sounding capacity in clear skies and during daytime only, plus other difficulties (overlapping emission plumes, complicated wind patterns, etc.) will still be limiting in some times or areas.
- ✓ The atmospheric information gathered from space will be completed by other types of data

=> next presentations on ICOS cities (other measurements) and high-resolution inventories (other types of data)

CoCO2

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- Chevallier, F., et al. (2022). Large CO_2 emitters as seen from satellite... Geophysical Research Letters, 49, e2021GL097540. https://doi.org/10.1029/2021GL097540
- Potier, E., et al. (2022). Complementing XCO_2 imagery … to monitor CO_2 emissions from fossil fuels on a regional to local scale, Atmos. Meas. Tech., 15, 5261–5288, https://doi.org/10.5194/amt-15-5261-2022
- Rey-Pommier, A., et al. (2022). Quantifying NO_x emissions in Egypt using TROPOMI observations, Atmos. Chem. Phys., 22, 11505–11527, https://doi.org/10.5194/acp-22-11505-2022

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