LEGO-4-AQ: An AQ policy support service based on the synergistic use of LEO, GEO, and in-situ monitoring

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LEGO-4-AQ: addressing ATMOS 2021 recommendations

ATMOS-2021 Recommendations	
Air Quality and Ozone	
R1	Air quality space-based observations referred mainly to NO_2. Major progress is expected on the simultaneous exploitation of NO_2 with other satellite products such as SO_2, aerosols and CO. The amount of information should be maximised by combining datasets from in-situ, ground-based remote sensing observations, as well as models. The advantages and limitations of each dataset should also be considered in future studies. Beyond that, the potential of AI should be further explored regarding e.g. dataset selection, retrieval methodology, and automated feature detection.
R2	TROPOMI NO_2 observations are widely used for air quality monitoring at global and city scale. The most recent product update has shown some important improvements, but only parts of the time series are available. The audience recommends a timely full reprocessing of the product.
R3	Two existing challenges require attention for further increasing the societal benefits of space-based AQ products and improve their utility for human exposure studies: • Robust and accurate methods for converting NO_2 column to surface concentrations should be further developed (e.g. based on modelled surface-to-column ratios, machine learning, etc.) • Health/exposure applications, particularly in urban areas, require even higher-resolution satellite AQ products than those provided by TROPOMI. Aside from launching higher-resolution instruments this could be achieved by further developing smart algorithms for increasing the spatial resolution and thus add value to the existing instruments (e.g. by oversampling techniques, synergies with other datasets/EO data/models, geostatistics, machine learning)

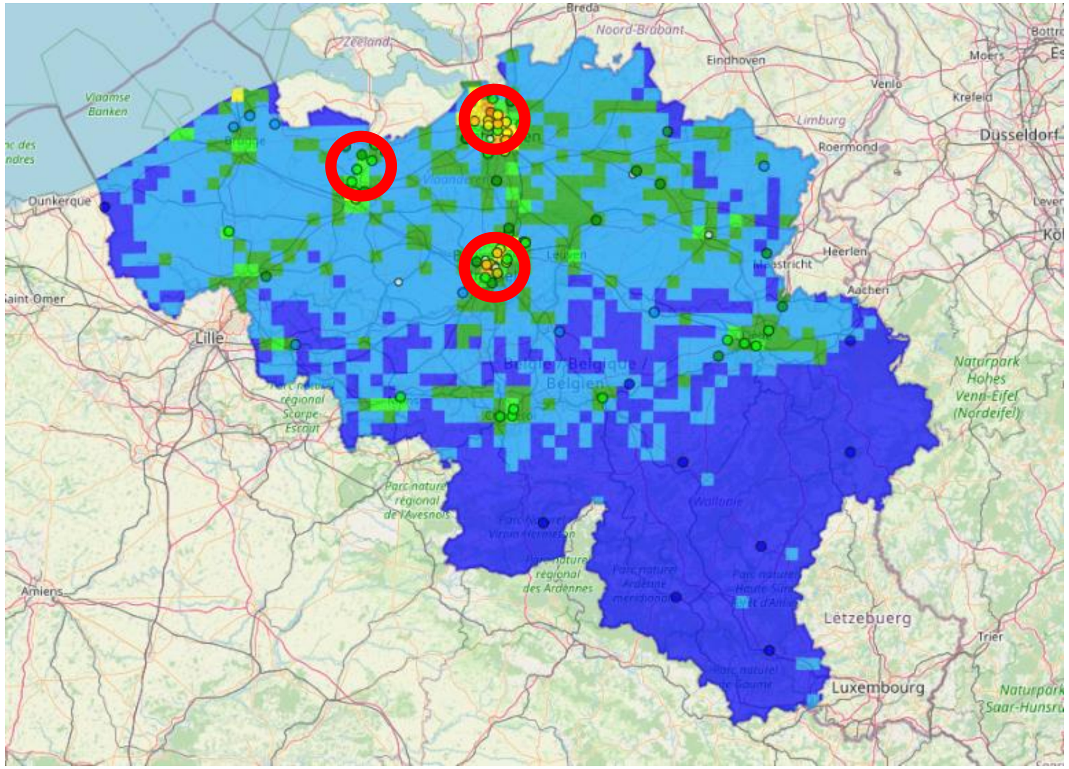
Synergistic use of oversampled RPRO S5P and in-situ data to create a temporally consistent near-surface NO_2 data set at urban resolution.

Context: space-based AQ monitoring at various scales

Increasing number of **local** regulations put into place to improve AQ, often on a **city** scale. For instance:

- Gradually tightening Low Emission Zones (LEZ)
- Traffic circulation plans in many smaller cities
- Financial stimuli for insulation, electrification,…

In-situ measurements of NOx, O_3, PM10, PM2.5 and BC are the standard for AQ monitoring ⇨ **spatially sparse data sets, made contiguous by (model-based) interpolation.**



Annual mean (2019) NO_2 concentration, data interpolated in-situ data (at 4x4km^2) (RIO model, IRCEL-CELINE)

AQ monitoring from space

Challenges for the uptake of satellite AQ data by policy makers and other stakeholders

Challenges are technical, communicational, and legislative:

- *Spatio-temporal **resolution** lower than classical methods combining near-surface data and modelling*
- *Relation to **near-surface concentrations** is not straightforward*
- ***Accuracy** (incl. selection biases due to cloud cover, processor changes,…)*
- ***Multiple platforms** with different properties: LEO+GEO; S5P, S4, S5, CO2M, S3…*
- *Data/**information** (and metadata) **format***

Two general classes of solutions:

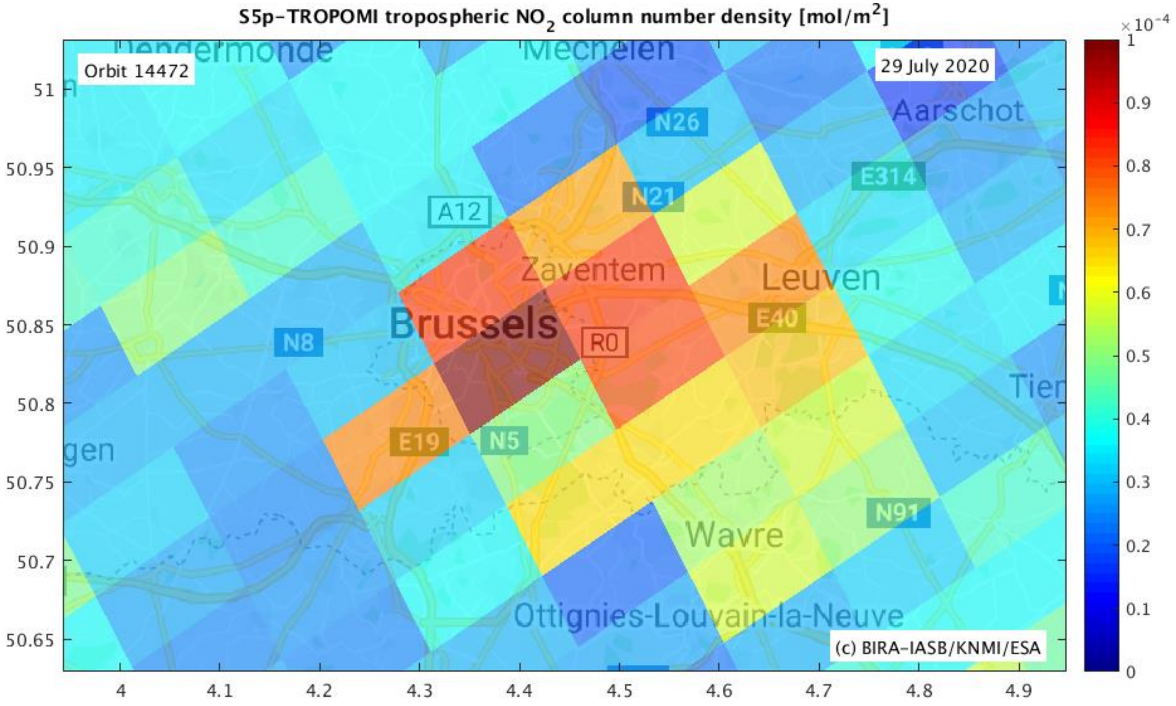
I. Include the satellite data into a comprehensive modelling system incl. meteo. data, emission inventories, chemistry schemes (e.g., CAMS) or similar based on ML/NN.

II. An (almost) purely observational approach, based on a synergistic use of measurement data, avoiding the use of reported emission estimates.

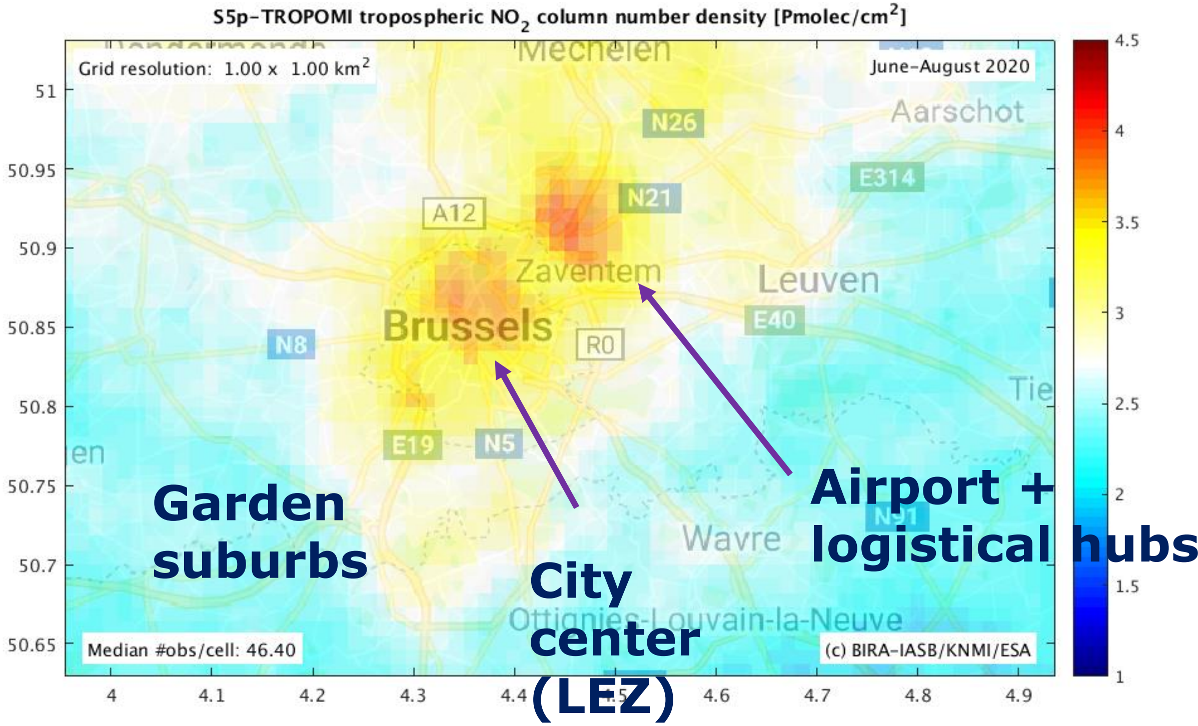
LEGO-4-AQ (initially LEGO-BEL-AQ), through an EO + in-situ/monitoring collaboration

Balancing spatial and temporal resolution: S5-P TROPOMI tropospheric NO_2

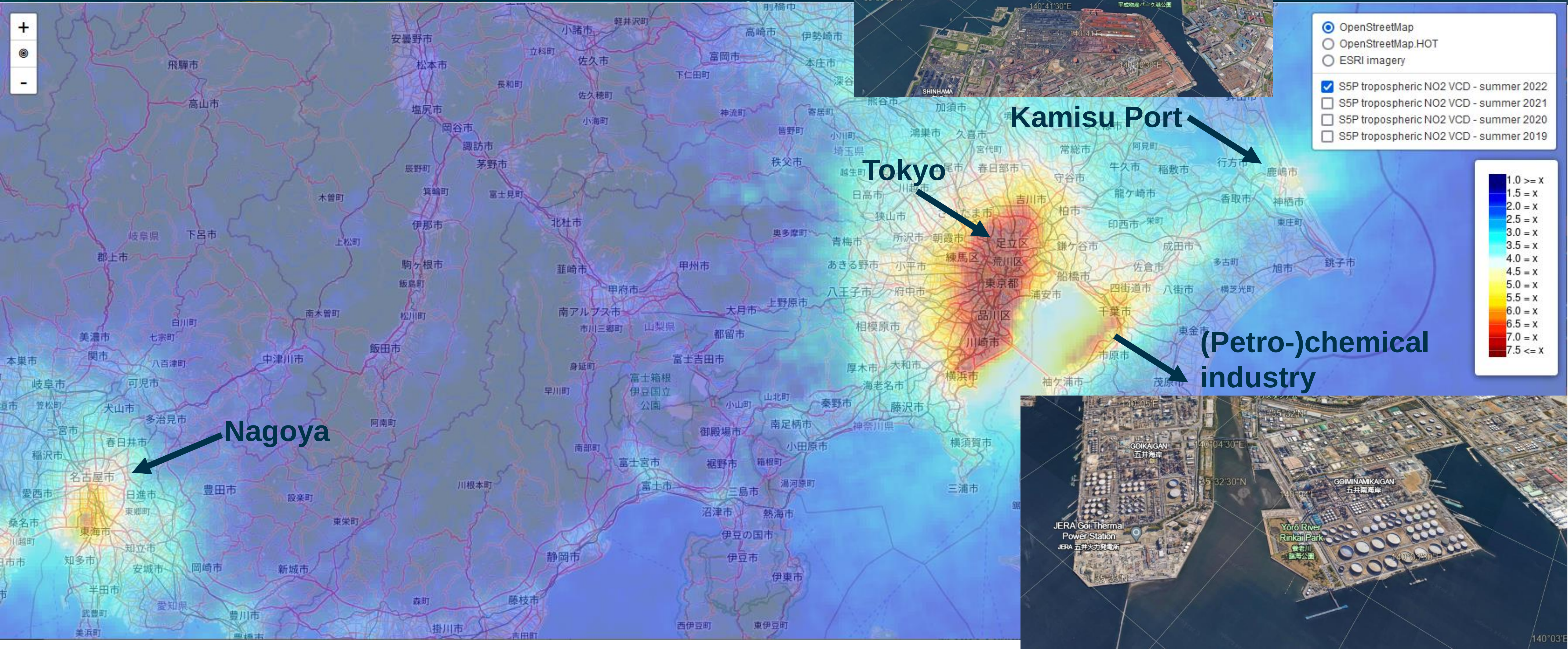
A single Sentinel-5p overpass over Belgium
Nominal ground resolution at nadir: 3.5 x 5.5 km²



3 months of Sentinel-5p data, area-weighted average at 1.0 x 1.0 km²



Balancing spatial and temporal resolution: S5-P TROPOMI tropospheric NO_2



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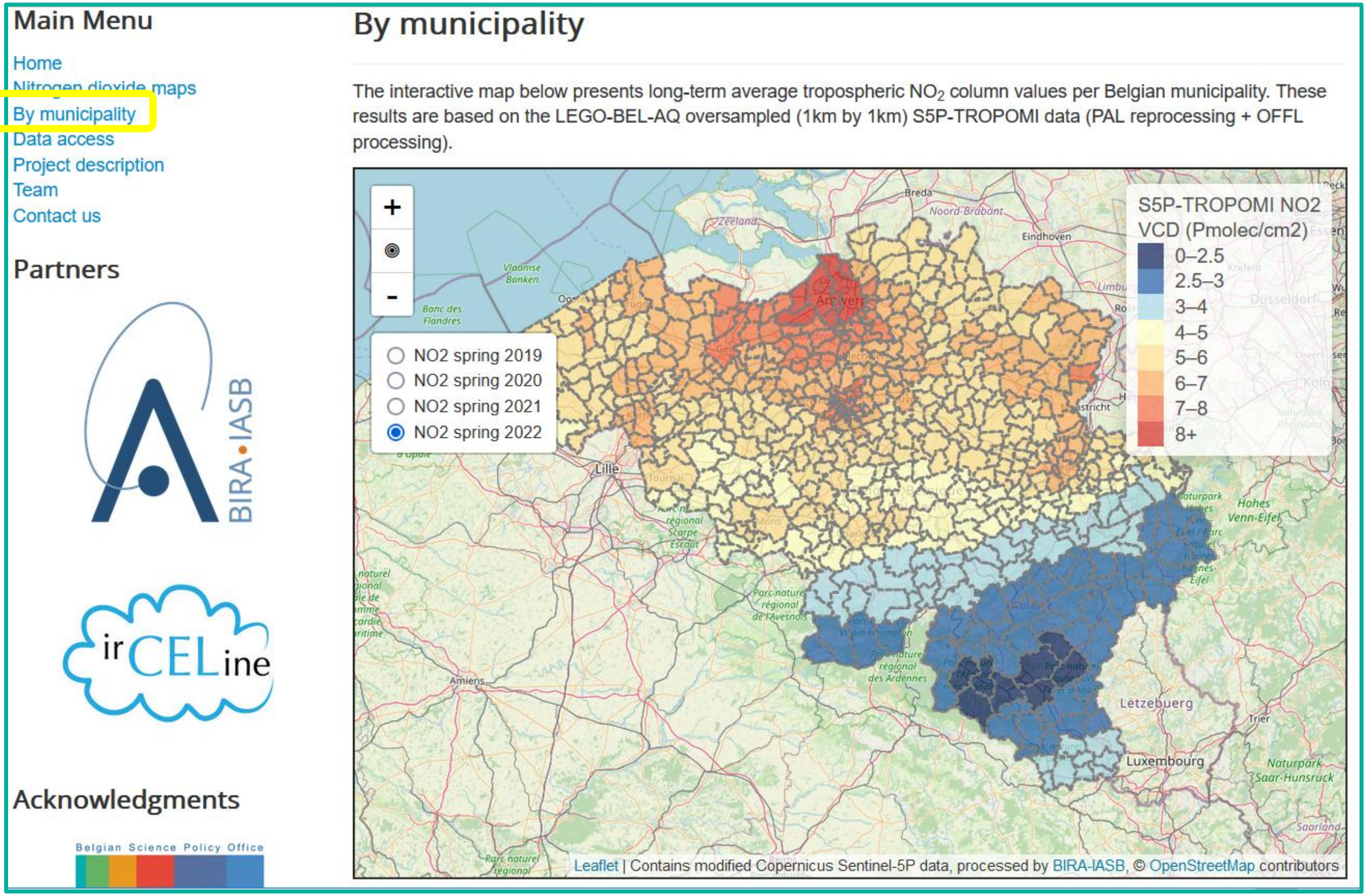
Balancing spatial and temporal resolution: S5-P TROPOMI tropospheric NO_2

Support policy making, monitoring and assessment by tailoring information to the different administrative levels, i.e.:

i. Federal
ii. Region
iii. Province
iv. Municipality



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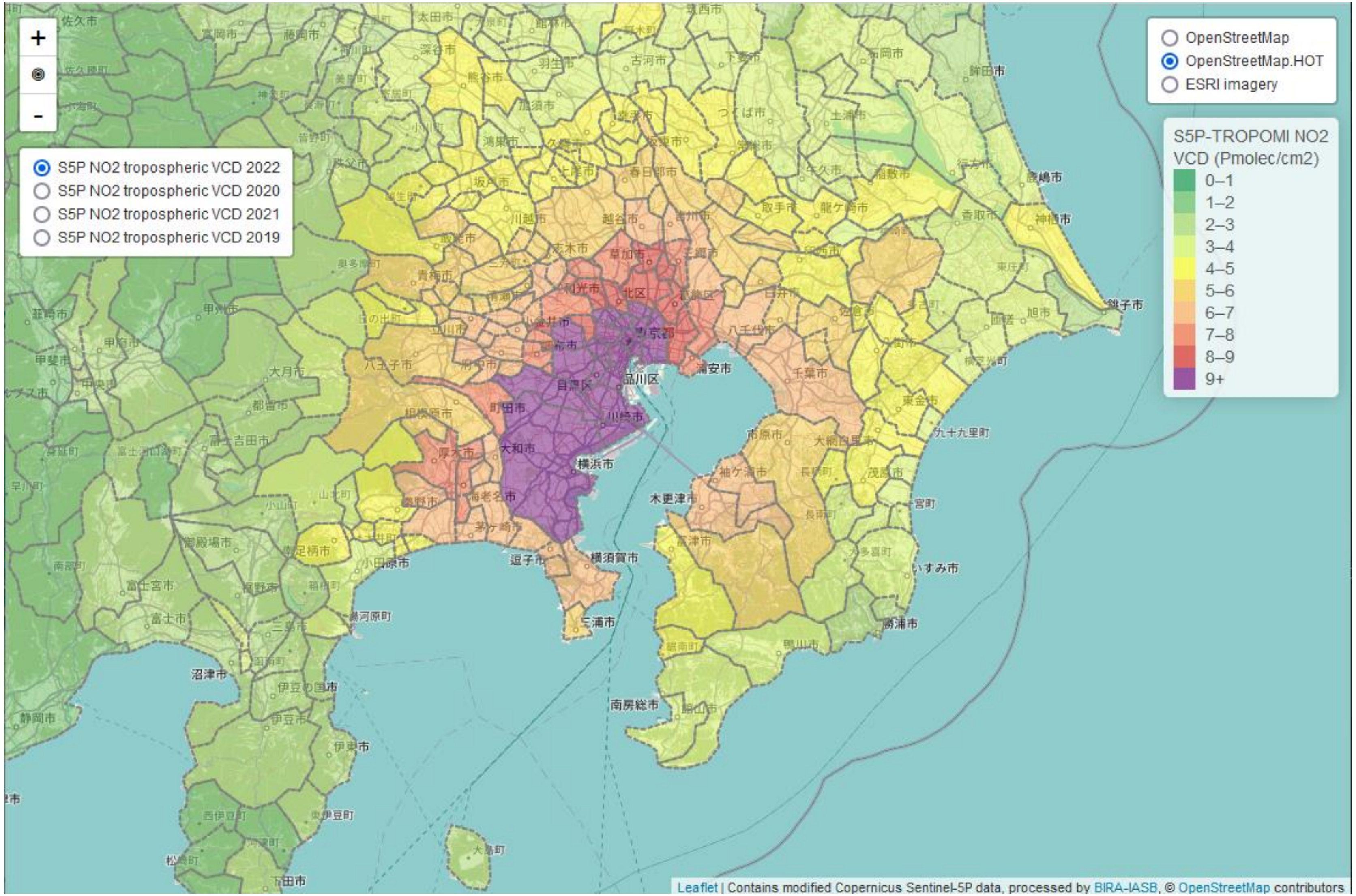

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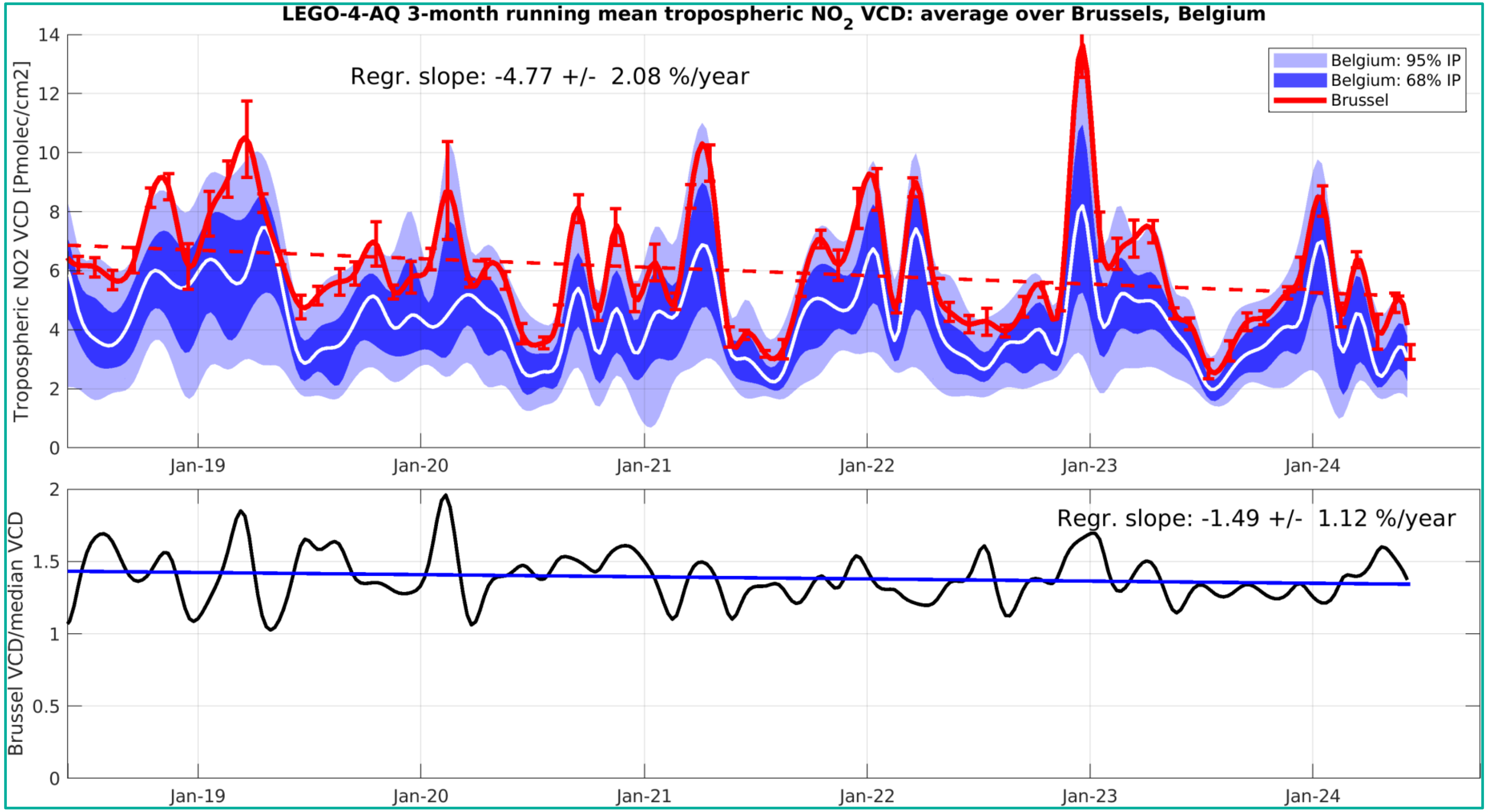
Impact of AQ policy: multi-annual trend

Brussels, Belgium (LEZ since 2018, gradually tightening)

Linear regression (on exactly 6 years of data): -5%/year

Linear regression relative to Belgian median: -1.5%/year



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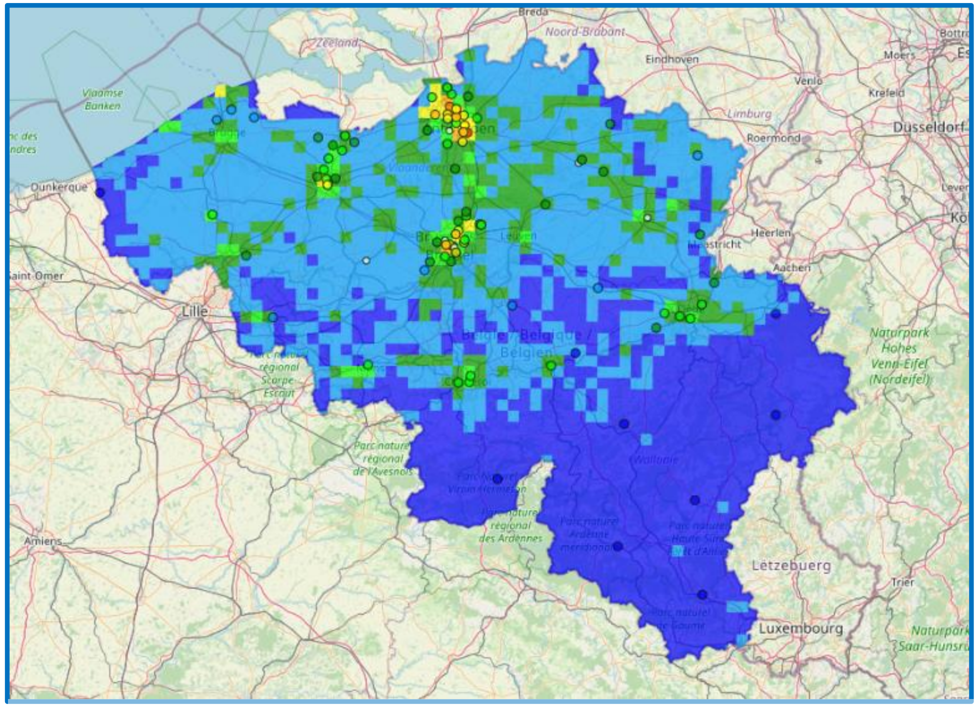
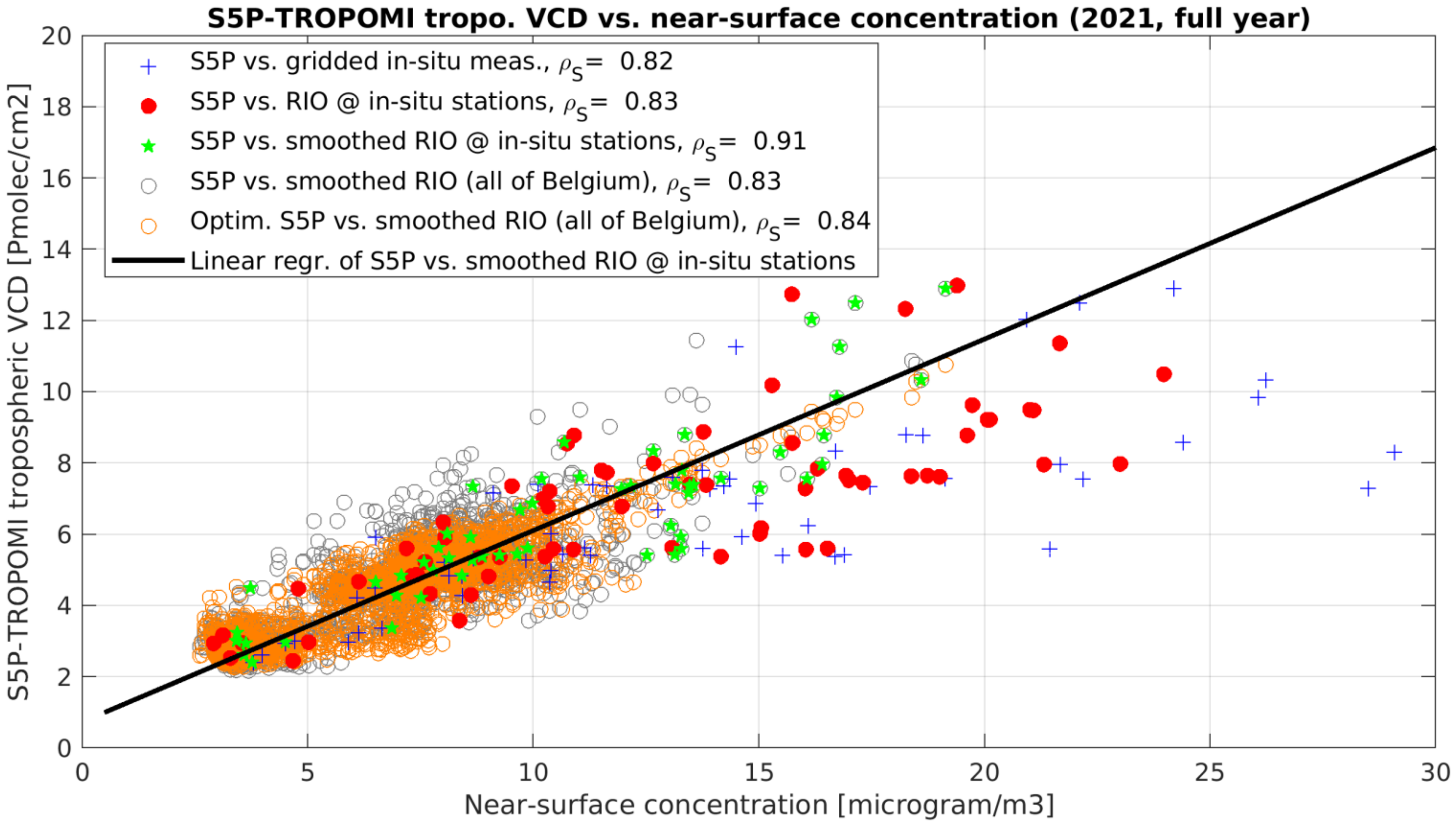
Conversion to near-surface concentrations



Annual mean (2019) NO_2 concentration, interpolated in-situ data (4x4km²) (RIO model, IRCEL-CELINE)

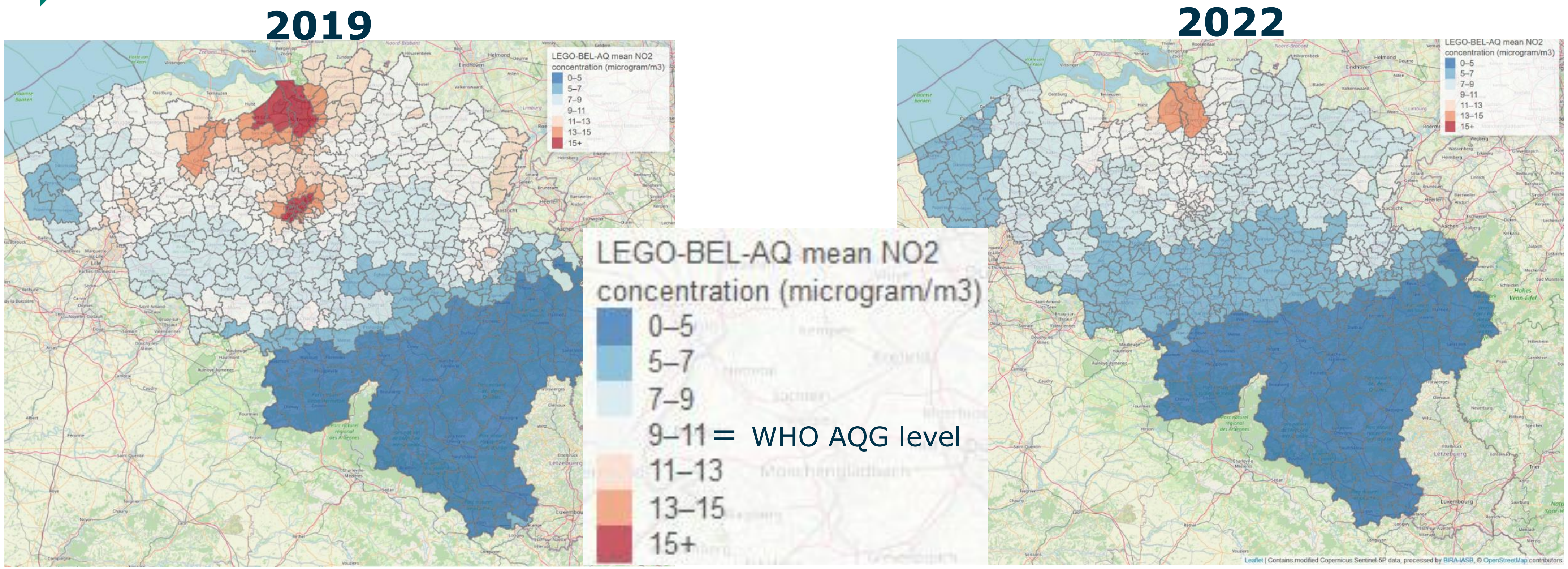


VCDs correlate rather well (>0.8) with near-surface concentrations over the Belgian domain.

→ **Linear calibration with residual Kriging (a.k.a. Regression Kriging)**

Conversion to near-surface concentrations

LEGO-4-AQ synergistic S5P + in-situ near-surface NO_2 product



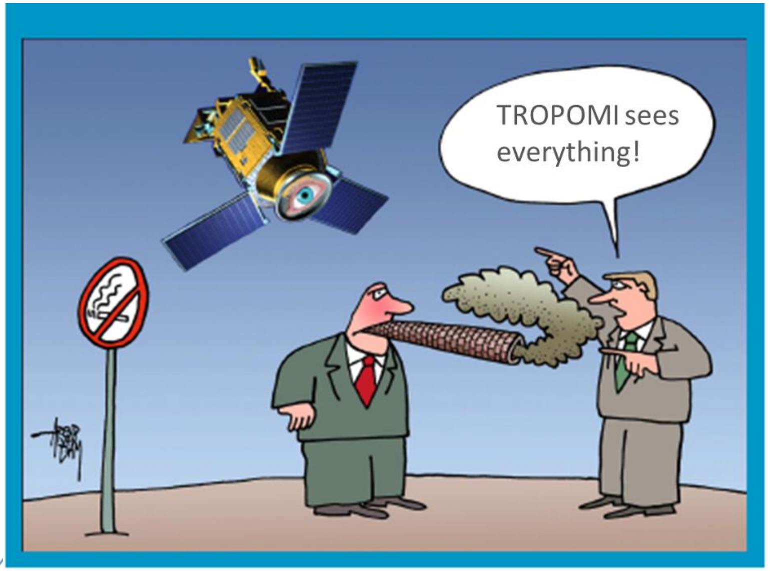
Strong reduction in annual municipal mid-day near-surface NO_2 concentrations

Uncertainty estimates: systematic < 0.5 microgram/m^3 (5%), random < 2 microgram/m^3 (20%)

LEGO-4-AQ: conclusions and (additional) recommendations

Conclusions:

- Satellites bring **improved spatial representativeness** through contiguous coverage.
- **Oversampling brings valuable increase in resolution** at an “acceptable” expense.
- **Regression Kriging** to in-situ data allows construction of a **purely observational near-surface product.**
- Reaching and involving AQ stakeholders requires **tailored information** and helps to focus the work.
- Impact of LEZ not obvious: decrease appears to be more general for “polluted” Belgium



ATMOS 2021 R1 through R3 remain topical as much remains unexplored; community exchange on the various methods and results is essential.

Additional (sub)recommendations:

- The vertical distribution (and changes thereof) needs more **observational** constraints (if not from space, from ground-based remote sensing and in-situ).
- **Uncertainty characterization and validation** of these products needs to target the intended use (e.g., quantification of L3 clear-sky biases, impact of aerosol loading, long-term stability,…).